NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: CIT 734

COURSE TITLE: OBJECT ORIENTED TECHNOLOGY

COURSE GUIDE

CIT 734
OBJECT ORIENTED TECHNOLOGY

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Published by
National Open University of Nigeria

Printed 2014

ISBN: 978-058-809-X

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INTRODUCTION

Welcome to Object Oriented Technology. This course is a 2 credit unit course and it is a post-graduate level course. The course will be available to all students in the M.Ed Educational Technology programme and PGD in Information Technology for Teachers.

The course is made up of twenty (20) units, which have been grouped into four modules:

- The Object Orientation Paradigm
- Object Oriented Analysis and Design
- Object Oriented Programming with JAVA
- Object Oriented Programming with C++

Although there are no compulsory prerequisites for this course, a non-trivial understanding of computer operations is necessary before commencing the course. This course is not a course in any particular programming language however you are introduced to the fundamentals of JAVA and C++ programming languages. You are expected to be able to write programs and compile the examples and exercises provided in this course material. The JAVA Development Kit and C++ compiler are provided with the course material and website addresses are also provided for those who may wish to download the JAVA SDK (Standard Development Kit) and the C++ compiler. No previous programming experience in Object-oriented programming languages is assumed, however, students are expected to have had experience in a conventional programming language like C or Pascal.

In the last two modules of this course you are expected to use the JAVA Development Kit and the C++ compiler to compile and execute the provided exercises, as a result you are required to undertake practical computing work, so you will need a computer to complete this unit. A computer system with the following minimum configuration will be suitable.

Pentium 233 MHz CPU
Microsoft Windows 98
VGA display and monitor
16MB RAM
500MB free space hard disk
Mouse and Keyboard

This Course Guide tells you briefly what the course is about, what course materials you will be using and how you can walk your way through these materials.

WHAT YOU WILL LEARN IN THIS COURSE

The overall aim of Object-Oriented Technology is to introduce the concept of Objects as it relates to Object-oriented analysis and design and object-oriented programming. During this course you will be introduced to object-oriented concepts and some of its applications. You will also learn about other programming techniques and the evolution of object-oriented approach to programming.

For the purpose of clarity and better understanding, I have explained object-oriented programming with specific reference to two programming languages (Java and C++) these are not the only object-oriented languages.

COURSE AIMS

The aim of the course can be summarized as follows:

- to introduce the concept of object-orientation
- to introduce object-oriented concepts
- to introduce object-oriented software design
- to introduce you to software engineering concepts and software quality issues as it relates to object-oriented design and analysis
- to give you a concrete understanding of object-oriented programming
- to provide basic knowledge of programming in an object-oriented language
- to demonstrate to you the use of object-oriented concepts in programming

COURSE OBJECTIVES

To achieve the aims set out above, the course sets overall objectives. In addition, each unit also has specific objectives. The unit objectives are always included at the beginning of a unit; you should read them before you start working through the unit. You may want to refer to them during your study of the unit to check on your progress. You should always look at the unit objectives after completing a unit. In this way you can be sure that you have done what was required of you by the unit.

Set out below are the wider objectives of the course as a whole. By meeting these objectives you should have achieved the aim of the course as a whole.

On successful completion of this course, you should be able to:

- Explain basic object-oriented concepts
- Describe object-oriented programming technique
- Explain the principles of software engineering
- Describe Software Life Cycle
- Explain object-oriented approach to software design and analysis
- Apply object-oriented techniques in programming
- Write programs in C++ and Java Programming Languages
- Compile and Run programs in C++ and Java Programming Languages using the provided compilers

COURSE MATERIALS

Major components of the course are:

1. Course Guide
2. Study units
3. Assignment File

You must also have access to a computer system and have the C++ and Java compilers provided on the CD-ROM installed on the computer.

STUDY UNITS

There are 20 units in the course, as follows;

Module 1 Object Orientation Paradigm

Unit 1 Introduction to Object-Oriented Concepts
Unit 2 More Object-Oriented Concepts
Unit 3 Relationships
Unit 4 Survey of Programming Techniques

Module 2 Object-Oriented Analysis And Design

Unit 1 Software Engineering
Unit 2 Software Quality Concepts
Unit 3 Landmarks of Object-Oriented Analysis and Design
Unit 4 Object-Oriented Analysis and Design
Unit 5 Object-Oriented Software Design

Module 3 Object-Oriented Programming In Java

Unit 1 Your First Cup of JAVA
Unit 2 A Closer look at the "Hello World" Sample
Unit 3 Object-Oriented Programming Concepts in Java
Unit 4 Translating Concepts into Code
Unit 5 JAVA Language Basics 1 (Variables & Operators)
Unit 6 JAVA Language Basics 2 (Expressions & Statements)

Module 4 Object-Oriented Programming In C++

Unit 1 Introduction to C++
Unit 2 C++ Language Basics
Unit 3 C++ Expressions and Statements
Unit 4 Classes I
Unit 5 Classes II

COMPUTER SOFTWARE

You will be expected to undertake practical activities using JAVA SDK and Turbo C++ Compiler. The JAVA SDK and the C++ compiler are provided on CD-ROM with the Course materials. The files are zipped (compressed), you are expected to unzip them using WINZIP.EXE provided also on the CD-ROM.

ASSIGNMENT FILE

In this file you will find all the details of the work you must submit to your tutor for marking. The marks you obtain for these assignments will count towards the final mark you obtain for this course. There are eighteen (18) assignments in this course.

ASSESSMENT

There are two aspects of the assessment of the course. First are the tutor-marked assignments; second, there is a written examination.

In tackling the assignments, you are expected to apply information, knowledge and techniques gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the stipulated deadlines. The work you submit to your tutor for assessment will count for 45% of your total course mark.

At the end of the course you will need to sit for a final written examination of two hours' duration. This examination will count for 55% of your total course mark. The examination will consist of

questions, which reflect the types of exercises and tutor marked problems you have previously encountered. All areas of the course will be assessed.

Use the time between finishing the last unit and sitting for the examination to revise the entire course. You might find it useful to review your exercises and tutor marked assignments before the examination. The final examination covers information from all parts of the course.

COURSE MARKING SCHEME

The following table lays out how the actual course marking is broken down.

Assessment	**Marks**
Assignments 1 – 18	Only the best 15 TMAs are counted (You are encouraged to do all the TMAs) 15 * 3.00% each = 45% of course marks
Final Examination	55% of course marks
Total	100% of course marks

COURSE OVERVIEW

Module: Unit	**Title of Work**	**Weeks activity**	**Assessment (end of unit)**
	Course Guide		
1:1	Introduction to object-oriented		1
1:2	More object-oriented concepts		2
1:3	Relationships		3
1:4	Survey of Programming		4
2:1	Software Engineering		5
2:2	Software Quality Concepts		6
2:3	Landmarks of Object-Oriented Analysis and		7
2:4	Object-oriented Design and		8
2:5	Object-oriented Software Design		9
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4:3	C++ Expressions and Statements		16
4:4	Classes 1		17
4:5	Classes II		18
	Revision		

HOW TO GET THE MOST FROM THIS COURSE

In distance learning the study units replace the lecturer. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your pace, and at a time and place that suit you best. Think of it as reading the lecture instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your set books or other material, and when to undertake computing practical work. Just as a lecturer might give you an in class exercise, you study units provide exercises for you to do at appropriate points.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit. You should use these objectives to guide your study. When you have finished the unit you
must go back and check whether you have achieved the objectives. If you make a habit of doing this you will significantly improve your chances of passing the course.

Exercises are interspersed within the units, and answers are given.

Working through this exercises will help you to achieve the objectives of the unit and help you to prepare for the assignments and examination.

The following is a practical strategy for working through the course.

l. Read this Course Guide thoroughly
2. Organize a study schedule. Refer to the `Course Overview' for more details.

3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get into difficulties with your schedule, please let your tutor know before it is too late.
4. Turn to Unit 1 and read the introduction and the objectives for the unit.
5. Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow.
6. Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study materials or consult your tutor.
7. When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
8. When you have submitted an assignment to your tutor for marking, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments.
9. After completing the last unit, review the course and prepare yourself for final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives listed on this Course Guide.

SUMMARY

Object-Oriented Technology is intended to provide you with sound foundation of knowledge about the Object-orientation concept and how it applies to software design, software analysis and programming. In order to achieve this you have been introduced to object-oriented concepts like Encapsulation, polymorphism, Inheritance etc. You are familiar to many of the buzzwords of object-oriented technology (e.g. objects, messages, classes, instances, interface etc). You have also been taught how to apply these object oriented concepts in design, analysis and programming. Upon completion of this course, you will be equipped with basic knowledge and skills necessary for the design and analysis of object-oriented software as well as skill needed for programming in an object-oriented programming language.

To gain the most from this course you should try to apply the knowledge and skills that you have learned in this course in your career. I hope that you are able to apply the knowledge and skills from this course throughout your career.

I wish you success with the course and hope that you will find it both the NOU and wish you every success in your future.

MAIN COURSE

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MODULE 1 OBJECT ORIENTATION PARADIGM

Unit 1 Introduction to Object-Oriented Concepts
Unit 2 More Object-Oriented Concepts
Unit 3 Relationships
Unit 4 Survey of Programming Techniques

UNIT 1 FUNDAMENTAL CONCEPTS OF OBJECT-ORIENTED TECHNOLOGY

CONTENTS

1.0 INTRODUCTION

This unit is a -general introduction to the fundamental concepts of object-oriented technology. The unit introduces the concept of objects, classes and methods and the role they play in object-oriented software.

2.0 OBJECTIVES

By the end of this unit, you should be able to

- define objects, classes and methods and identify their relationships
- explain the concept of object-oriented programming
- identity object-oriented languages

3.0 MAIN CONTENT

3.1 The Object Paradigm

3.1.1 What is an Object?

An object is a "black box" which receives and sends messages. A black box actually contains code (sequences of computer instructions) and data (information which the instructions operates on).

An Object

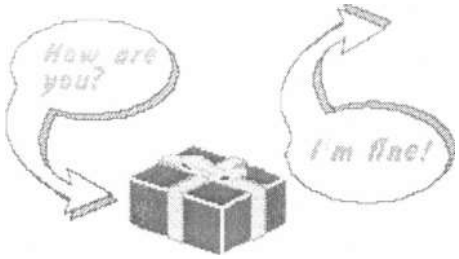
An object is a .software unit composed q1' a set of data and a set of operations for accessing and processing that data. Traditionally, code and data have been kept apart. For example, in the C language, units of code are called functions, while units of data are called structures.

Functions and structures are not formally connected in C. A C function can operate on more than one type of structure, and more than one function can operate on the same structure.

Not so for object-oriented software! In object-oriented programming, code and data are merged into a single indivisible thing -- an object.

This has some big advantages, as you'll see in a moment. But first, why use the "black box" metaphor for an object? A primary rule of object-oriented programming is this: as the user of an object, you should never need to peek inside the box!

Why shouldn't you need to look inside an object`? For one thing, all communication to it is done via messages. The object which a message is sent to is called the receiver of the message. Messages define the interface to the object. Everything an object can do is represented by its message interface. So you shouldn't have to know anything about what is in the black box in order to use it.

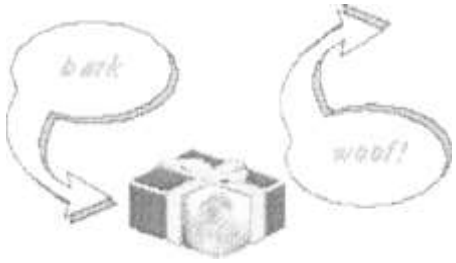


And not looking inside the object's black box doesn't tempt you to directly modify that object. If you did, you would be tampering with the details of how the object works. Suppose the person who programmed the object in the first place decided later on to clanged some of these details? Then you Would be in trouble. Your software would no longer work correctly! But so long as you just deal with objects as black boxes via their messages, the software is guaranteed to work. Providing access to an object only through its messages. While keeping the details private is called information hiding (technically speaking, encapsulation).

Why all this concern for being able to change software? Because experience has taught us that software changes. A popular adage is that "software is not written, it is re-written". And some of the costliest mistakes in computer history have come from software that breaks when someone tries to change it.

3.1.2 Classes

How are objects defined? An object is defined via its class, which determines everything about an object. Objects are individual instances of a class. For example, you may create an object called Spot from class Dog. The Dog class defines what it is to be a Dog object, and all the "dog-related" messages a Dog object can act upon. All object-oriented languages have some means, usually called a factory, to "manufacture" object instances from a class definition.



Spot
You can make more than one object of this class, and call them Spot, Fido, Rover, etc. The Dog class defines messages that the Dog objects understand, such as "bark". "fetch", and "roll-over".

3.1.3 Methods

You may also hear the term “method” used. A method is simply the action that a message carries out. It is the code, which gets executed when the message is sent to a particular object.

A method can be applied to (or invoked on) a specific object or the class itself. To be more precise a method consists of the following:

- a name
- a (possibly empty) list of input names, called parameters or arguments, and their types
- an (optional) output type, called the return type (if the return type is 'void', then it means that there is no return type)
- a body of executable. The body of executable code is called the implementation of the method.

Arguments are often supplied as part of a message. For example, the "fetch" message might contain an argument that says what to fetch, like "the-stick". Or the "roll-over" message could contain one argument to say how fast, and a second argument to say how many times.

SELF ASSESSMENT EXERCISE 1

Identify the Object, Class and Method in this: I have two Balls, a football and volleyball. The balls could bounce fast or slow and could roll left or right.

3.2 Object Oriented Programming

3.2.1 What is Object-Oriented Programming?

Since the early days of computing, programmers have looked for ways to manage the complexity of programming computers. Because a computer's central processing unit (CPU) works by fetching and executing simple instructions from memory, early computer programs were a sequence of such machine instructions that had to be loaded into memory through a set of switches or through a numeric keypad.

Assembly language improved the situation by enabling us to use mnemonic names for the machine instructions and symbolic names for memory locations. A translator called the assembler converts assembly language programs into machine code. Assemblers soon started providing special commands or directives that allowed programmers to group basic data items into structures with assigned names. With a program's tasks broken down into procedures and data organized into

structures. assembly language provided reasonable programming facilities. However, the close connection between assembly language and the machine code means that assembly language forces you to think of the program in terms of the machine instructions that the underlying CPU can execute.

Higher-level languages such as FORTRAN, BASIC, Pascal, and C largely eliminate the close ties to the CPU's machine instructions by providing standard data types such as integers, floating-point numbers, and character strings that can be used in expressions and statements each of which is translated by a compiler into many machine instructions.

Most recent applications are written in a combination of these high-level languages and some assembly language. The accepted programming style has been to organize related data items using programming constructs such as Pascal RECORDs or C STRUCTs and then treat the resulting block of data as a single unit. Once the data structures are laid out, the application is written as a collection of procedures that manipulate these structures.

Although the traditional "design the data structures and write the functions to manipulate them" approach to programming has served us well. there is no denying that the complexity of software is increasing in keeping with more powerful computer hardware. With ever-increasing hardware capabilities such as faster CPUs, better graphics, and easier networking, users have come to expect software to have greater functionality. Users now routinely expect programs to include features such as a window-based graphical user interface, transparent access to data stored in mini- or mainframe computers, and the ability to work in a networked environment. Faced with this complexity, more programmers are starting to use object-oriented programming (OOP). OOP is a new way of organizing code and data that promises increased control over the complexity of the software development process.

Object-oriented programming is nothing new; its underlying concepts are data abstraction, inheritance, and polymorphism (explained in later units). All three have been around for quite some time (for example, in languages such as SImula67 and Smalltalk). What is new is the increasing interest in OOP among programmers in general.

The term object-.oriented programming (OOP) is widely used, but experts cannot seem to agree on its exact definition. However, most experts agree that OOP involves defining abstract data types (ADI) representing complex real-world or abstract objects and organizing your program around the collection of AD Fs with an eye toss and exploiting their common features. The term data abstraction refers to the process of

defining ADTs: inheritance and polymorphism refer to the mechanisms that enable you to take advantage of the common characteristics of the AD-I's-the objects in OOP. These terms are clearly explained later in the course.

The term abstract data type, or ADT for short, refers to a programmer-defined data type together with a set of operations that can be performed on that data.

Before you jump into OOP, take note of two points. First, OOP is only a method of designing and implementing software. Use of object-oriented techniques does not impart anything to a finished software product that the user can see. However, as a programmer implementing the software, you can gain significant advantages by using object-oriented methods, especially in large software projects. Because OOP enables you to remain close to the conceptual, higher-level model of the real-world problem you are trying to solve, you can manage the complexity better than with approaches that force you to map the problem to lit the features of the language. You can take advantage of the modularity of objects and implement the program in relatively independent units that are easier to maintain and extend. You can also share code among objects through inheritance.

SELF ASSESSMENT EXERCISE 2

Mention three underlying concepts of object oriented programming

Practical Examples

If you wanted to add two numbers, say, I and 2, in an ordinary, non-object-oriented computer language like C (don't worry --you don't need to know any C to follow this), you might write this:

```
a = l; b = 2;
c = a + b;
```

This says,

“Take a, which has the value 1, and b, which has the 2, and add them together using the C language‘s built – in addition capability. Take the result, 3, and place it into the variable called c.” Now, here’s the same thing expressed in Smalltalk, which is a pure object- oriented language:

```
a : = 1.
b : = 2.
```

C : = a+b.

Wait a minute. Except for some minor notational differences, the looks exactly the same ! Okey, it is the same, but meaning is dramatically different.

In Smalltalk, this says,

"Take the object a, which has the value l, and send it the message which included the argument b, which. In turn, has the value 2. Object a. receives this message and performs the action requested. which is to add the value of the argument to yourself. Create a new object, give this the result, 3, and assign this object to c."

Hmm. This seems like a fill- more complicated way of' accomplishing exactly the same thing! So why bother?

The reason is that objects greatly simplify matters when the data get more complex. Suppose you wanted a data type called list, which is a list o1'names. In C, list would be defined as a structure.

struck list {<definition of list structure data here> } ,

list a, b, c;
a = "John Jones";
b = "Suzy Smith";

Let's try to add these new a and b in the C language:

Guess what? This doesn't work. The C compiler will generate an error when it tries to compile this because it doesn't know what to do with a and b. C compilers just know how to add numbers. Period. But a and b are not numbers. One can do the same thing in Smalltalk, but this time, list is made a class, which is a subclass of the built-in Smalltalk class called "String":

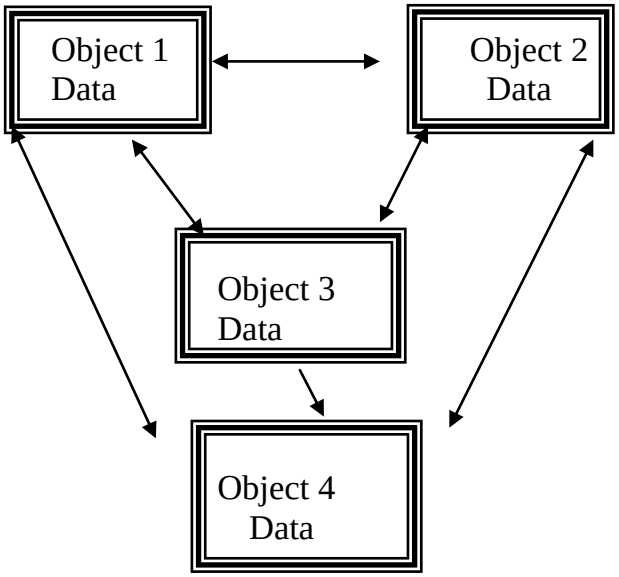
a := List from String : `John Jones'.
b := List from String : `Suzy Smith'.
c := a + b.

The first two lines simply create List objects a and b from the given strings. This now works, because the list class was created with a method which specifically "knows" how to handle the message. For example. it might simply combine the argument with its own object by sticking them together with a comma separating them (this is done a single line of Smalltalk I:). So c will have the new value:

'John Jones, Suzy Smith'

3.2.2 Object-Oriented Programming Languages

Object-oriented programming is a programming method that combines data and instructions into a self-sufficient "object". In an object-oriented program, the design is represented by objects. Objects have two sections, fields (instance variables) and methods. Fields represent what an object is. Methods represent how an object is used. These fields and methods are closely tied to real world characteristics and use of the object. An object is used by means of its methods. The following figure shows a view of object-oriented programming.



A programming language is called object-oriented if it supports the concepts of data abstraction, class, and more advanced concepts such as inheritance and polymorphism.

There are almost two dozens major object-oriented programming languages in use today. But the leading commercial Object-Oriented languages are far fewer in number. These are:

C'++
Smalltalk
Java

C++
C++ is an object-oriented version of C. It is compatible with C (it is actually a superset), so that existing C code can be incorporated into

C++ programs. C++ programs are fast and efficient, actualities which helped make C an extremely popular programming language. It sacrifices some flexibility in order to remain efficient. However. C++ uses compile-time binding, which means that the programmer must specify the specific class of an object, or at the very least, the most general class that an object can belong to. This makes for high run-time efficiency and small code size, but it trades off some of the power to reuse classes.

C++ has become so popular that most new C compilers are actually C/C++ compilers. However, to take full advantage of object- oriented programming, one must program (and think!) in C++, not C. This can often be a major problem for experienced C programmers. Many programmers think they are coding in C++, but instead are only using a small part of the language's object- oriented power.

Smalltalk

Smalltalk is a pure object-oriented language. While C++ makes some practical compromises to ensure fast execution and small code size, Smalltalk makes none. It uses run-time binding, which means that nothing about the type of an object need be known before a Smalltalk program is run.

Smalltalk programs are considered by most to be significantly faster to develop than C++ programs. A rich class library that can be easily reused via inheritance is one reason for this. Another reason is Smalltalk's dynamic development environment. It is not explicitly compiled, like C++. This makes the development process more fluid, so that "what if scenarios can be easily tried out, and classes definitions easily refined. But being purely object -oriented, programmers cannot simply put their toes in the Object-oriented waters, as with C++. For this reason, Smalltalk generally takes longer to master than C++. But most of this time is actually spent learning object- oriented methodology and techniques, rather than details of a particular programming language. In fact, Smalltalk is syntactically very simple, much more so than either C or C++.

Unlike C++, which has become standardized, The Smalltalk language differs somewhat from one implementation to another. The most popular commercial "dialects" of Smalltalk are:

Visual Works from Parc Place -Digitalk, Inc.
Smalltalk/V and Visual Smalltalk from Pare Place-Digitalk Inc.
Visual Age from IBM

Java

Java is the latest, flashiest object -oriented language. It has taken the software world by storm due to its close ties with the Internet and Web browsers. It is designed as a portable language that can run on any web-enabled computer via that computer's Web browser. As such, it offers great promise as the standard Internet and Intranet programming language.

.Java is a curious mixture of C++ and Smalltalk. It has the syntax of' C++, making it easy (or difficult) to learn, depending on your experience. But it has improved on C++ in some important areas. For one thing, it has no pointers, low-level programming constructs that make for error-prone programs. Like Smalltalk, it has garbage collection, a feature that frees the programmer from explicitly allocating and de-allocating memory. And it runs on a Smalltalk-style virtual machine, software built into your web browser which executes the same standard compiled Java byte codes no matter what type of computer you have.

Java development tools are being rapidly deployed, and are available from such major software companies as IBM, Microsoft, and Symantec.

4.0 CONCLUSION

Object-Oriented programming offers a new and powerful model for writing computer software. Objects are "black boxes" which send and receive messages. This approach speeds the development of new programs, and, if properly used, improves the maintenance, reusability, and modifiability of software.

Object-oriented programming requires a major shift in thinking by programmers, however. The C++ language offers an easier transition via C, but it still requires an Object-oriented design approach in order to make proper use of this technology. Smalltalk offers a pure Object-oriented environment, with more rapid development time and greater flexibility and power. Java promises much for Web-enabling Object-oriented programs.

5.0 SUMMARY

In this unit you have learnt about objects and how they are defined through classes. You also learnt about the underlying concepts of object-oriented pro-ramming and some examples of object-oriented languages. We will build on theses concepts as we proceed in the course.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the following terms
   - Object
   - Class
   - Method

2. Describe Object-oriented programming

7.0 REFERENCES/FURTHER READING

Terry Mantic What is Object-Oriented Software Copyright 1995 – 1996 by Software Design Consultants, LL.C All rights reserved

Nabajyoti Barkakati, Object-Oriented Programming in C++, Prentice-Hall of India Private Limited, New Delhi – 110 001, 2001.

UNIT 2 MORE OBJECT ORIENTED CONCEPTS

CONTENTS

1.0 INTRODUCTION

In the previous unit you have learned about some basic object-oriented concepts. In this unit you will learn about some more object-oriented concepts.

2.0 OBJECTIVES

After completing this unit, you should be able to:

- explain encapsulation
- explain poltimorphism
- explain inheritance.

3.0 MAIN CONTENT

3.1 Encapsulation

Encapsulation is hiding parts of program that do internal things, and by their nature shouldn't be of concern to anybody from outside. Why is it good to hide anything? Because of two reasons:

1. You warn user of your code what lie can use safely, and what is not of his concern.
2. You can change (fix errors and enhance) what you liid, without influencing public part. User continues to use your code in the same manner, but it works better.

Imagine you are writing piece of software that does some common task (a graphic library for example). You are in a role of programmer writing for other programmers, and your relation with these programmers is similar to relation between them and end users. Although, end users don't know (nor they should) how the program is made, they are perfectly capable to use it efficiently through it's user interface. The same is true with programmers that use your library - don't waste their

time by making them know internal details of your code. Just provide efficient "user interface" and let them use your code only through that interface.

Maybe what you are writing is huge. There is lot of auxiliary/internal code. Line count is 10000+. Of course you are constantly developing it - fixing bugs and adding new features. Put yourself in the place of programmers who are using your code. Whenever you make a change, these poor fellows have to check if their code is compatible with the "new version" of your code. If you are selfish person, you might ask: "Why that should be my concern?". Well, IT IS YOUR CONCERN. It's perfectly possible (especially if you are not working in a team) that "other programmers" are actually you. If you are member of the team - remember, team wins, not an individual player!

The solution is to divide constant from mutating part. Every library/class/module... has part which has form that it has because it's logical and natural to be that way, and because communication with the outer world is conducted through it. The "communication channel" is permanent. Only the way messages that come through it are processed changes from time to time.

That constant communication channel is called interface. The rest is implementation. Classic programming tools, mainly modules and, in a lower level, blocks (begin.. end in Pascal, {} in C-like language), give fair set of possibilities to use encapsulation. OOP, however, has comprehensive model o1'encapsu1ation related to classes.

Every element (field or method) of one class can have one of these three levels of visibility:

1. Public elements are completely visible from outside of the class. They make interface to the outside world.
2. Private elements are visible only from methods of the class itself. In some languages, their visibility is extended to module in which class resides. They make implementation.
3. Protected elements are something between 1 and 2. To the outside world, they act same as the private elements, but they are completely visible from inherited child classes - they have public beliaviOUr for these classes. In some languages protected elements visibility is extend to module in which class resides. Although, strictly speaking, protected elements belong to implementation, they should be considered as interface to child classes.

Let's make one Delphi class:

```
TTriangle = class
private
        X,Y,A: integer;
        protected
         procedure Initialize;
public
         procedure Place(x_arg,y_arg: integer);
         procedure Draw;
published
end;
```

Just Initialize, Place and Draw methods can access X Y and A. No outer function can access X, Y and A. Initialize can be called from Draw, Place and all methods from child classes. Finally Place and Draw can be called from any place in which class itself is visible.

In addition, Delphi permits access to private and protected members from the same unit. Java has similar behaviour for packages. C++ is more rigorous (and, as the matter of fact, has no real modules) and there is no such visibility of private and protected members, but there is so-called fiend mechanism. Delphi supports fourth, published specified, which has role in visual programming. But this is not our topic in this point.

Inheritance

One of the most important, (and yet not completely solved) problems of programming states: "How not to re-invent a wheel again?". Differently said, problem is: how to write something that can be used more then one time. 1 admit, sounds weird.

However, anybody with intense programming experience, wrote similar (or same!) code in different programs, or even the same program. y

Why?

There are several reasons - one is traditional laziness of COMPLrter programmers. Simply, it was easier to ad-hoc do exactly what has to be done, exactly where it has to be done, than to try to extract a global solution, that can be later specialized for concrete cases. Such "copy-and-paste" programming (meaning copying pre-existing code to needed place and changing it slightly) is a way to finish the program fast and to make it work fast. But, the word "fast" doesn't mean "robust". In tills case, word "fast" means "nightmare" for maintenance and enhancement.

Not to blame only programmers, languages too didn't support "abstract" way of thinking that Would allow you to think Using concepts close to problem, not using concepts close to machine, such as bytes and pointers.

In classic "procedural" or "structure" programming, there are techniques to extract a code that handles some general task (although out some old dBase-like languages lack even these capabilities). Tile most Important technique of that kind are "procedures" (Or "functions" or "sub-routines "). Tile second important technique are "modules" (similar terms: "units", "packages", even "compilation units"). Modules appear ill three roles: 1) encapsulation 2) code reuse achieved thru procedures contained ill modules and 3) physical organization - a module is (in most languages) a file.

It seems tills solves the need for code reuse, but on the long track (and ill the large programs), we are trapped ill thinking on the machine level. riot problem level.

There are better, object-oriented solutions which don't negate classic techniques, but organize them on a higher level. Key solution is **inheritance.**

Inheritance is the way to **change or extend already existing class (parent class)** by making it's **child (inherited, derived) class** and writing **only changed** or enhanced part ill that child class. Everything else (part ol'tlle parent that doesn't need to be changed), **child class inherits from the parent.** There is an important fact: child remains linked to it's parent - when parent is changed, child changes as well (in it's inherited part). So, if you fix a bug within the parent, you automatically fixed that bug ill all children. If you enhance parent, you enhanced all children.

Polymorphism

Let's say we need bunch of different objects that are used ill the same way. Typical example. Widely used ill OOP literature, are geometric shapes. Wouldn’t be nice to let user fill some data structure with squares, triangles, circles,... and call Draw for all of them, without further complications (such as explicit type checking).

Traditional solution is use of classical structures (records ill Pascal) or unions that contain data type identification field. This approach suffers from two weaknesses.

1. Bad abstraction and non-optimal use of space because all types]lave to be placed ill one format. If we rationalized use of space, that usually means we "flattened" the types too much, and they are no more a good representation of the problem we are trying to solve. In the other hand. if we wanted to achieve ill optimal abstraction level, there is probably lot of wasted space because physical formats of types are very different. Of course. tricks are always available (such pointers and dynamic memory allocation) but that implicates a different set of problems.

2. Non-standardized type identification fields. You have to memorize what value identifies what type. Enumerated types can help, but simply it's not an optimal solution.

Polymorphism is ability of objects to act depending of their run-time type.

Without inheritance, polymorphism makes no sense. Without inheritance it's impossible to have object of one (child) class placed instead of another (parent) class. So, with inheritance, we need a mechanism to deal with awareness of the run-time (not the compile-time) class of the particular object, no mater it's placed instead of different compile-time declared class.

Polymorphism is such mechanism.

Polymorphism is extremely important for effective use of inheritance. Frequently, it is used to "persuade" methods of parent class to use redefined methods of the child class. A good example can be seen in the inheritance.

The other situation is what I wrote in the beginning of this page: we have a number of objects with the same interface. but different behaviour. The solution is to create one base class that will contain all common methods. These methods should be virtual. After that, from that base class, we'll inherit all needed classes. Then, we'll declare an array (or list or whatever) whose elements are declared as instances of the base class, but in the run-time instances of child classes will be placed instead.

Virtual methods are methods aware of polymorphism.
In some languages (Smalltalk) all methods are virtual - polymorphism is always active. In most languages, however, you can declare a method as non-virtual, which ensures no other version is called (no matter that other version exists in a child class, and a method is called for instance

of the child class). You should be very careful when deciding do you need polymorphic or nonpolymorphic behaviour for particular method.

UNIT 3 RELATIONSHIPS

CONTENTS

1.0 INTRODUCTION

Whereas the previous units introduces the fundamental concepts of object-oriented programming, this unit presents more details about the object-oriented idea. We will use a pseudo language to describe most of the concepts described in this unit.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- explain types of relationships of classes
- describe inheritance and multiple inheritance
- define super class and subclass
- describe abstract classes

3.0 MAIN CONTENT

3.1 Relationship

Class Circle inherits all data elements and methods from point. There is no need to define them twice: We just use already existing and well-known data and method definitions.

On the object level we are now able to use a circle just as we would use a point, because a circle is-a point. For example, we can define a circle object and set its center point coordinates:

```
Circle acircle
acircle.setX (1)        /* Inherited from Point */
acircle.setY(2)
acircle.setRadius(3) /* Added by Circle */
```

"Is-a" also implies, that we can use a circle everywhere where a point is expected. For example, you can write a function or method, say move(), which should move a point in x direction:

```
move (Point apoint, int deltax) {
      apoint.setX(apoint.getX() + deltax)
```

As a circle inherits from a point, you can use this function with a circle argument to move its center point and, hence, the whole circle:

```
Circle  acircle
. . .
Move (acircle,10)     /* Move circle by moving */
/* its center point */
```

Let's try to formalize the term "inheritance":

Definition (Inheritance) Inheritance is the mechanism which allow a class A to inherit properties of a class B. we say "A inhere/.1' from ".object of class A thus/ how access to attributes and methods' of class 13 without the need to redefine them. The following definition defines two terms with which we are able to refer to participating classes when they use inheritance.

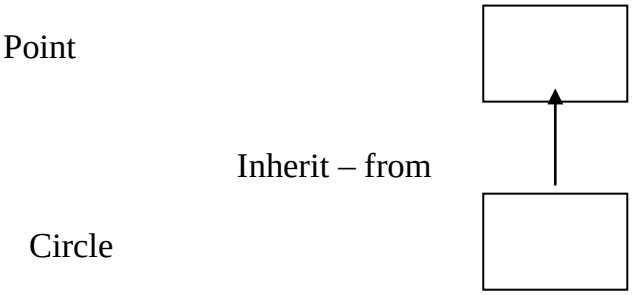
Definition (Super class Subclass) If class A inherits, from class 13, then B is called super class of A. A is called succors of 13. Objects of a subclass can be used where objects of the corresponding super class are expected. This is due to the fact that objects of the subclass share the same behaviour as objects of the superclass.

In literatures you may also find other terms for "superclass" and "subclass". Super classes are also called parent classes. Subclasses may also be called child classes or just derived classes.

Of course, you can again inherit from a subclass, malting this class the superclass of the new subclass. This leads to a hierarchy of superclass/subclass relationships. If you draw this hierarchy you get an inheritance graph.

A common drawing scheme is to use arrowed lines to indicate the inheritance relationship between two classes or objects. In our examples we have used "inherits-from". Consequently, the arrowed line starts from the subclass towards the superclass as illustrated in Figure 3.5.

Figure 3.5: A simple inheritance graph.



In some literatures you also find illustrations where the arrowed lines are used just the other way around. The direction, in which the arrowed line is used, depends on how the corresponding author has decided to understand it.

Anyway, within this unit, the arrowed line is always directed towards tile Super class.

In the following sections an unmarked arrowed line indicates "inherit-from".

Exercise 2.1
What is another name for a subclass ?

Answer
Child class or derived class

3.1.1 A-Kind-Of relationship

of various objects such as points, circles, rectangles, triangles and many more. For early object you provide a class definition. For example, the point class just defines a point by its coordinates:

```
class Point {
        attributes:
 int x, y

methods:
         setX(int newX)
        getX ( )
```

setY (int newY)
getY ( )

You continue defining classes of your drawing program with a class to describe circles. A circle defines a center point and a radius:
class Circle { attributes: int x, y, radius

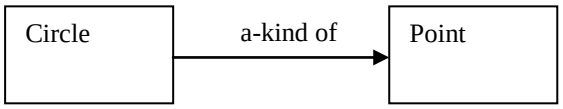
methods:
setX (int newX)
getX ( )
setY (int newY)
getY ( )
setRadius(newRadius)
getRadius()

Comparing both class definitions we can observe the following:

- Both classes have two data elements x and y. In the class Point these elements describe the position of the point, in the case of class Circle they describe the circle's center. Thus, x and v have the same meaning in both classes: They describe the position of their associated object by defining a point.
- Both classes` offer the same set of methods to get and set the value of the two data elements x and Y.
- Class Circle "adds" a new data element radius and corresponding access methods.

Knowing the properties of class Point we can describe a circle as a point plus a radius and methods to access it. Thus, a circle is -a-kind-of' point. However, a circle is somewhat more specialized". We illustrate this graphically as shown in Figure 3.1.

Figure 3.1: Illustration of "a-kind-of' relationship.



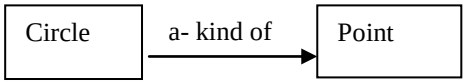
In this and the following figures, classes are drawn using rectangles. Their name always starts with an uppercase letter. The arrowed line indicates the direction of the relation, hence, it is to be read as "Circle is a-kind-of Point."

3.1.2 Is-A relationship

The previous relationship is used at the class level to describe relationships between two similar classes. If we create objects of two such classes we refer to their relationship as an "is-a" relationship.
Since the class Circle is a kind of class Point, an instance of Circle, say acircle, is a point. Consequently, each circle behaves like a point. For example, you can move points in x direction by altering the value of-Y. Similarly, you move circles in this direction by altering their x value.

Figure 3.2 illustrates this relationship. In this and the following figures, objects are drawn using rectangles with round corners. Their name only consists of lowercase letters.

Figure 3.2: Illustration of "is-a" relationship.



3.2 Part-Of relationship

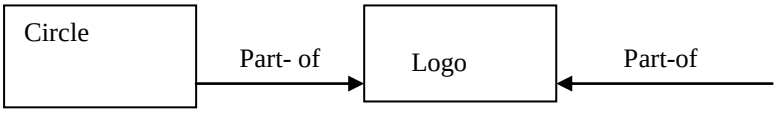
You sometimes need to be able to build objects by combining them OLrt of structure or record construct to put data of various types together.

Let's come back to our drawing program. You already have created several classes for the available figures. Now you decide that you want to Dave a special figure which represents your own logo which consists of a circle and a triangle. (Let's assume, that you already Dave defined a class Triangle.) Thus, your logo consists of two parks or the circle and triangle are park-of your logo:

```
class Logo {
attributes:
  Circle circle
  Triangle triangle

methods:
set(Point where
)
```

This is illustrated in Figure 3.3

Figure 3.3: Illustration of "part-of' relationship.



3.3 Has-A relationship

This relationship is just the inverse version of the part-of relationship. Therefore we can easily add this relationship to the part-of illustration by adding arrows in the other direction (Figure 3.4).

Figure 3.4: Illustration of -has-a" relationship.

Circle	Part-of	Part- of	Triangle
	It as -at	It is- a	

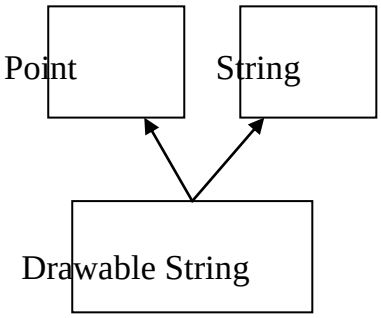
3.4 Multiple Inheritance

One important object-oriented mechanism is multiple inheritance. Multiple inheritances does not mean that multiple subclasses share the same superclass. It also does not mean that a subclass can inherit from a class which itself is a subclass of another class.

Multiple inheritances means that one subclass can have more than one superclass. This enables the subclass to inherit properties of more than one superclass and to "merge" their properties.

As an example consider again our drawing program. Suppose we already have a class String which allows convenient handling of text. For example, it might have a method to append other text. In our program we would like to use this class to add text to the possible drawing objects. It would be nice to also use already existing routines such as move () ~ to move the text around. Consequently, it makes sense to let a drawable text have a point which defines its location within the drawing area. Therefore we derive a new class Drawable String which inherits properties from Point and String as illustrated in Figure 3.6

Figure 3.6: Derive a drawable string which inherits properties of Point and Siring.



In our pseudo language we write this by simply separating the multiple super classes by comma:

class DrawableString inherits from Point, String {
attributes:
/* All inherited from super classes */
methods:
/* All inherited from super classes */

We can use objects of class DrawableString like both points and strings. Because a drawablestring is- a point we can move them around`

DrawableString string
Move (string, 10)
…
Since it is a siring, we can append other text to them: cistring.append ("The red brown fox ...") Now it's time for the definition of multiple inheritances:
Definition (Multiple Inheritance) If class A inherits from more than one class, ie. A inherits from BI, B2, ..., B, we speak of **multiple inheritance.** This may introduce **naming conflicts** in A if at least two of its super classes define properties with the same name.

The above definition introduce naming conflict which occur if more than one super class of a subclass use the same name for either attributes or methods. For an example, let's assume, that class String defines a method which sets the string to a sequence of "X" characters. The question arises, what should be inherited by Drawable String? The Point, String version or none of them?

These conflicts can be solved in at least two ways:

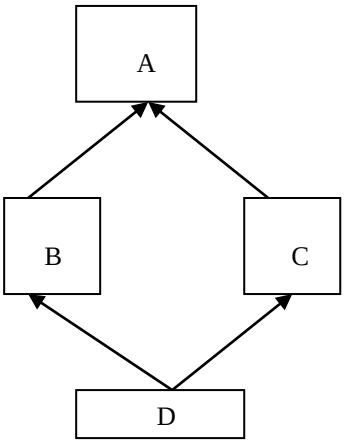
- The order in which the super class is provided define which property will be accessible by the conflict causing name. Others will be "hidden".

- The subclass must resolve the conflict by providing a property with the name and by defining how to use the ones from its super classes.

The first solution is not very convenient as it introduces implicit consequences depending on the order in which classes inherit from each other. For the second case, subclasses must explicitly redefine properties which are involved in a naming conflict.

A special type of naming conflict is introduced if a class D multiply inherits from room super classes B and C which themselves are derived from one superclass A. This leads to an inheritance graph as shown in Figure 3.7.

Figure 3.7: A name conflict introduced by a shared superclass of super classes used with multiple inheritance.



The question arises what properties class D actually inherits from its super classes B and C. Some existing programming language solve this special inheritance graphs by deriving D with

- The properties of, A plus
- The properties of B and C without the properties they have inherited from A.

Consequently, D cannot introduce naming conflicts with names of class A. However, if B and C add properties with the same name, D runs into a naming conflict.

Another possible solution is, that D inherits from both inheritance paths. In this solution, D owns two copies of the properties of A: one is inherited by B and one by C.

Although multiple inheritance is a powerful object-oriented mechanism the problems introduced with naming conflicts have lead several authors

to "doom" it. As the result of multiple inheritance can always be achieved by using (simple) inheritance some object-oriented languages even don't allow its use. However, carefully used, under some conditions multiple inheritance provides an efficient and elegant way of formulating things.

3.5 Abstract Classes

With inheritance we are able to force a subclass to offer the same properties like their super classes. Consequently, objects of a subclass behave like objects of their super classes.

Sometimes it make sense to only describe the properties of a set of objects rollout knowing the actual behaviour beforehand. In our drawing program example, each object should provide a method to draw itself on the drawing area. However. the necessary steps to draw an objects depends on its represented shape. For example, the drawing routine of a circle is different from the drawing routine of a rectangle.
Let's call the drawing nettled print(). To force every drawable object to include SLICK method, we define a class Drawable object from which every other class in our example inherits general properties of drawable objects:

```
abstract class Drawable object {
 attributes:

methods:
setX (int newX)
getX ()
setY (in newY)
getY ()
print o )
```

We introduce the new keyword abstract here. It is used to express the fact that derived classes must redefine" the properties to fulfill the desired functionality. Thus from the abstract class' point of view, the properties are only specified but not fully classified. The full definition including the semantics of the properties must be provided by derived classes. Now, every class in our drawing program example inherits properties from the general drawable object class. Therefore, class point changes to:

```
class Point inherits  from Drawable object { attributes:
int x, y methods:
 setX(int newX)
 getX ( )
```

setY (int newY)
getY ( )
print() /* Redefine for Point */

We are now able to force every drawable object to have a method called print which should provide functionality to draw the object within the driven;., area. The superclass of all draw able objects, class Drainable object, does not provide any functionality for drawing itself. It is not intended to create objects from it. This class rather specifies properties which must be defined by every derived class. We refer to this special type of classes as abstract classes:

Definition (Abstract Class) .-1 class A is called **abstract class** if it is only used as a supclass for other classes. Class A only specific properties. It is not used to create objects. Derived classes must define the properties of A.

Abstract classes allow us to Structure our inheritance graph. However, we actually don't want to create objects from them: we only scant to express common characteristics of a set of classes.

4.0 CONCLUSION

Classes are related one way or the other.You have learnt about different types of class relationships in this unit. The concept of inheritance and multiple inheritance among related classes have also been discussed in this unit.

5.0 SUMMARY

In this unit we have used a pseudo language to describe the concept of oriented language like C++ or Java which will be discussed later in the course.

6.0 TUTOR-MARKED ASSIGNMENT

i. Describe with diagrams three types of relationships
ii. Define the following terms
    a. Inheritance
    b. Multiple Inheritance
    c. Abstract Class

7.0 REFERENCE/FURTHER READING

Peter Miller - Introduction to Object Oriented Programming in C++ Globewide Network Academy (GNA)

UNIT 4 SURVEY OF PROGRAMMING TECHNIQUES

CONTENTS

1.0 INTRODUCTION

This unit is a short survey of programming techniques. We use a simple example to illustrate the particular properties and to point out their main ideas and problems. Roughly speaking, we can distinguish the following learning curve of someone who learns to program:

- Unstructured programming,
- Procedural programming,
- Modular programming and
- Object-oriented programming.

This unit is organized as follows. Sections 3.1 to 3.3 briefly describe the first three programming techniques. Subsequently, we present a simple example of how modular programmining' can be used to implement a singly linked list module (section 3.4). Using this we state a few problems with this kind of technique in section 3.5. Finally, section 3.6 describes the fourth programming technique.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

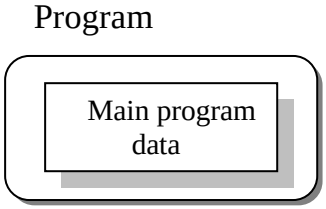
- explain unstructured programming, procedural programming, modular programming and object-oriented programming
- identify some problems with modular programming technique.

3.0 MAIN CONTENT

3.1 Unstructured Programming

Usually, people start learning programming by writing's small and simple programs consisting only of one main program. Here "main program" stands for a sequence of commands or statements which modify data which is global throughout the whole program. We can illustrate this as shown in Fig. 3. I .

Figure 3.1: Unstructured programming. The main program directly operates on global data.

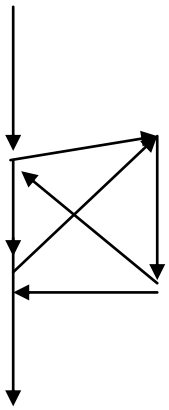


As you should know, this programming techniques provide tremendous disadvantages once the program gets sufficiently large. For example, if the same statement sequence is needed at different locations within the program, the sequence must be copied. This has lead to the idea to extract these sequences, name them and offering a technique to call and return from these procedures.

3.2 Procedural Programming

With procedural programming you are able to combine returning sequences of after the sequence is processed, flow of control proceeds right after the position where the call was made (Fig. 3.2).

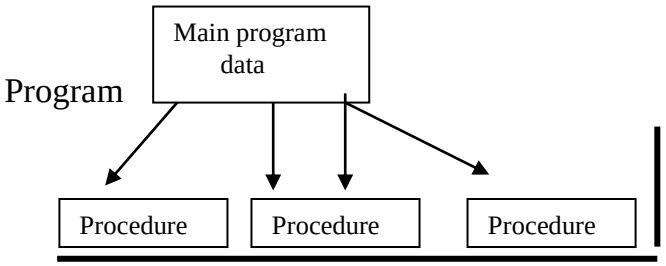
Figure 3.2: Execution of procedures. After processing flow of controls proceed where the call was made.



With introducing parameters as well as procedures (subprocedures programs can now be written more structured and error free. For example, if a procedure is correct, every time it is used it produces correct results. Consequently, in cases of errors you can narrow your-search to those places which are not proven to be correct.

Now a program can be viewed as a sequence of procedure calls. The main program is responsible to pass data to the individual calls, the data is processed by the procedures and, once the program has finished, the resulting data is presented. Thus, the flow of duel can be illustrated as a hierarchical graph, a tree, as shown in Fig. 3.3 for a program with no subprocedures.

Figure 3.3: Procedural programming. The main program coordinates calls to procedures and hands over appropriate data as parameters.



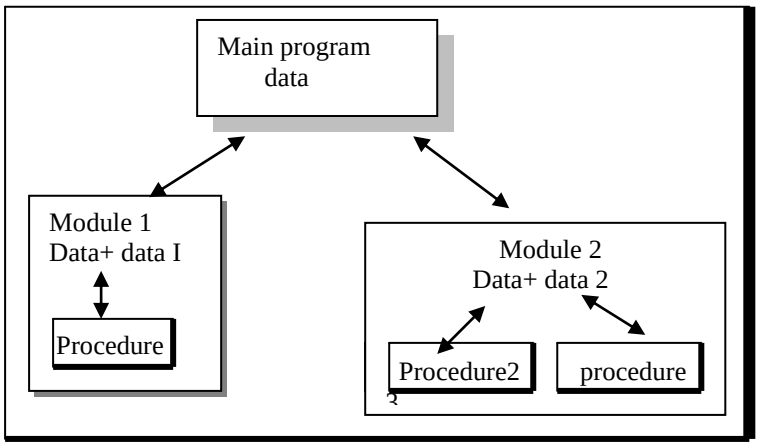
To sum up: Now we leave a single program which is divided into small pieces in other programs, they must be separately available. For that reason, modular programming allows grouping of procedures into modules.

3.3 Modular Programming

With modular programming procedures of a common functionality are grouped together into separate modules. A program therefore no longer

consists of only one single part. It is now divided into several smaller parts which interact through procedure calls and which form the whole program
(Fig. 3.4)

Figure 3.4: Modular programming. The main program coordinates calls to procedures in separate modules and hands over appropriate data as parameters.



Each module can have its own data. This allows each module to manage an internal slate which is modified by calls to procedures of this module. However, there is only one state per module and each module exists at most once in the whole program.

3.4 An Example with Data Structures

Programs use data structures to store data. Several data structures exist, for example lists, trees, arrays, sets, bags or queues to name a few. Each of these data structures can be characterized by their structure and their access methods .

3.4.1 Handling Single Lists

You all know singly linked lists which use a very simple structure, consisting of elements which are strung together, as shown in Fig. 3.5).

Figure 3.5: Structure of a singly linked list.

Singly linked lists just provides access methods to append a new element to their end and to delete the element at the front. Complex data structures might use already existing ones. For example a queue can be structured like a singly linked list. However, queues provide access methods to put a data element at the end and to get the first data element (first in first-out (FIFO) behaviour).

We will now present an example which we use to present some design concepts. Since this example is just used to illustrate these concepts and problems it is neither complete nor optimal. Suppose you want to program a list in a modular programming language such as C or Modula-2. As you believe that lists are a common data structure, you decide to implement it in a separate module. Typically, this requires you to write two files: the interface definition and the implementation file. Within this unit we will use a very simple pseudo code which you should understand immediately. Let's assume, that comments are enclosed in -/* ... */". Our interface definition might then look similar to that below:

```
*
* Interface definition for a module which implements
* a singly linked list for storing data of any type.
*/

MODULE Singly-Linked-List-1
BOOT, list_ initialize();
BOOT, list append(ANY data);
BOOT, list_ delete();
        list end();
ANY list getFirts ();
ANY list getNext();
BOOT, list isEmpty();
END Singly-Linked-List-I
```

Interface definitions just describe what is available and not how it is made available. You hide the information of the implementation in the implementation file. This is a fundamental principle in software engineering, so let's repeat it: You hide information of the actual implementation (information hiding). This enables you to change the implementation, for example to use a faster but more memory consuming algorithm for storing elements with out the need to change other modules of your program: The calls to provide procedures remain the same.

The idea of this interface is as follows: Before using the list one has to call list initialize initialize variables local to the module. The following

two procedures implement the mentioned access methods append and delete. The append procedure needs a more detailed discussion. Function 1ist append() takes one argument data of arbitrary type. This is necessary since you wish to use your list in several different environments, hence, the type of the data elements to be stored in the list is not known beforehand. Consequently, you have to use a special type any which allows to assign data of any type to it. The third procedure list_ end() needs to be called when the program terminates to enable the module to clean up its internally used variables. For example you might want to release allocated memory.

With the next two procedures list getfirst () and list getNext() a simple mechanism to traverse through the list is offered. Traversing can be done using the follow in- loop:

```
ANY data;

data <- list getFirst();
WHILE data IS VALID DO
        Do Something(data);
        data <- list_getNext();

END
```

Now you have a list module which allows you to use a list with any type of data elements. But what, if you need more than one list in one of your programs?

3.4.2 Handling Multiple Lists

You decide to redesign your list module to be able to manage more than one list. You therefore create a new interface description which now includes a definition for a list handle. This handle is used in every provided procedure to uniquely identify the list in question. Your interface definition file of your new list module looks like this:

```
*
* A list module for more than one list.
*/

MODULE Singly-Linked-List-2

DECLARE TYPE list handle t;

list_ handle_ t  list-create();
```

```
list _destroy(list handle _t this);
BOOL        list _append(list handle _t this, ANY data);
ANY         list get First(list handle t this);


ANY         list_getNext(list handle _t this);
BOOL        list is Empty(list handle t this);

END         Singly-Linked-List-2;
```

You use DECLARE TYPE to introduce a new type list _ handle _t represents your list handle. We do not specify, how this handle is actually represented or even implemented. You also hide the implementation details of this type in your implementation file. Note the difference to the previous version where you just hide functions or procedures, respectively. Now you also hide information for a user defined data type called list- handle- t.

You use list create () to obtain a handle to a new thus empty list. Every other procedure now contains the special parameter This which just identities the list in question. All procedures now operate on this handle rather than a module global list.

Now you might say, that you can create list objects. Each such object can be defined to operate on this handle.

3.5 Modular Programming Problems

The previous section shows, that you already program with some object-oriented concepts in mind. However, the example implies some problems which we will outline now.

3.5.1 Explicit Creation and Destruction

In the example every time you want to use a list, you explicitly have to declare a handle and perform a call to list create to obtain a valid one. After the use of the list you must explicitly call list destroy with the handle of the list you want to be destroyed. If you want to use a list within a procedure, say, food you use the following code frame:

```
PROCEDURE fool) BEGIN
list-handle t myList;
myList <- list create();

/* Do something with myList
…
```

list destroy(myList);

END

Let's compare the list with other data types, for example an integer. Integers are declared within a particular scope (for example within a procedure). Once you've defined them, you can use them. Once you leave the scope (for example the procedure where the integer was defined) the integer is lost. It is automatically created and destroyed. Some compilers even initialize newly created integers to a specific value, typically () (zero).

Where is the difference to list "objects"? The lifetime of a list is also defined by its scope, hence, it must be created once the scope is entered and destroyed once it is left. On creation time a list should be
similar to the definition of an integer. A code frame for this would loot: like this:

PROCEDURE fool) BEGIN

list handle t myList; /* List is created and initialized */

/* Do something with the myList */

END /* myList is destroyed */

The advantage is, that now the compiler takes care of calling initialization and termination procedures as appropriate. For example. this ensures that the list is correctly deleted, returning resources to the program.

3.5.2 Decoupled Data and Operations

Decoupling of data and operations leads usually to a structure based on the operations rather than the data: Modules group common operations (such as those list ... () operations) together. You then use these operations by providing explicitly the data to them on which they should operate. The resulting module structure is therefore oriented on the operations rather than the actual data. One could say that the defined operations specify the data to be used.

In object-orientation, structure is organized by the data. You choose the data representations which best fit your requirements. Consequently, your programs get structured by the data rather than operations. Thus, it is exactly the other way around: Data specifies valid operations. Now modules group data representations together.

3.5.3 Missing Type Safety

In our list example we have to use the special type ANY to allow the list to carry any data we like. This implies, that the compiler cannot guarantee for type safety. Consider the following example which the compiler cannot check for correctness:

```
PROCEDURE fool) BEGIN
Some Data Type data;
Some0therType data2;
List_ handle t myList;

myList <- list_ create();
list append(myList, data);
list append(myList, data2); /* Oops */


END
```

It is in your responsibility to ensure that your list is used consistently. A element, However, this implies more overhead and does not prevent you from knowing what you are doing.

What we would like to have is a mechanism which allows us to specify on always the same, whether we store apples, numbers, cars or even lists. Therefore it would be nice to declare a new list with something like:

```
list_ handle_t<Apple> list;  /* a list of apples */
list handle t<Car> list2; /* a list of cars */
```

The corresponding list routines should then automatically return the correct data types. The compiler should be able to check for type consistency.

3.5.4 Strategies and Representation

The list example implies operations to traverse through the list. Typically a cursor is used for that purpose which points to the current element. This implies a traversing strategy which defines the order in which the elements of the data structure are to be visited.

For a simple data structure like the singly linked list one can think of only one traversing strategy. Starting with the leftmost element one successively visits the right neighbors until one reaches the last element. However, more complex data structures such as trees can be traversed

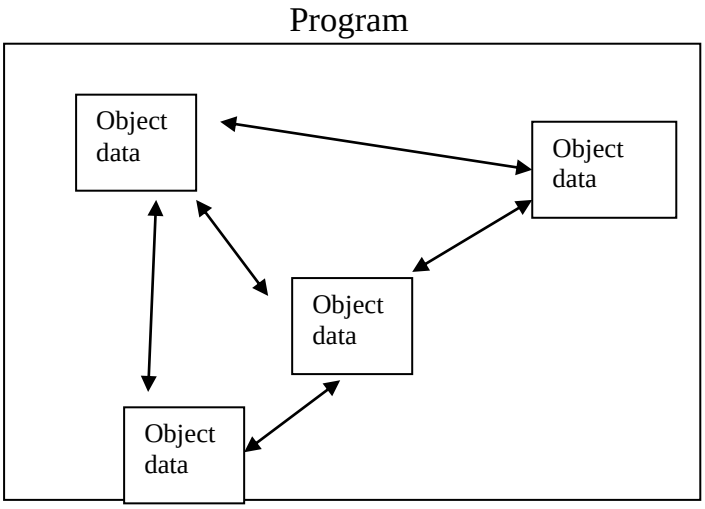
using different strategies. Even worse, sometimes traversing strategies depend on the particular context in which a data structure is used. Consequently, it makes sense to separate the actual representation or shape of the data structure from its traversing strategy.

What we have shown with the traversing strategy applies to other strategies as well. For example insertion might be done such that an order over the elements is achieved or not.

3.6 Object-Oriented Programming

Object-oriented programming solves some of the problems just mentioned. In contrast to the other techniques, we now have a web of interacting objects, each house-keeping its own state (Fig. 3.6).

Figure 3.6: Object-oriented programming. Objects of the program interact by sending messages to each other.



Consider the multiple lists example again. Tile problem here with modular use the procedures of the module to modify each of your handles.
In contrast to that, in object-oriented programming we would have as many list objects as needed. Instead of calling a procedure which we must provide with the correct list handle, we would directly send a message to the list object in question. Roughly speaking, each object implements its own module allowing for example many lists to coexist.

Each object is responsible to initialize and destroy itself correctly. Consequently, there is no longer the need to explicitly call a creation or termination procedure.

4.0 CONCLUSION

You might ask: So what isn't object –oriented technique. Just a more fancies- modular programming technique? You were right, if this would be all about object-orientation. Fortunately. It is not. From the previous units additional features of object-orientation were discussed which makes object oriented programming a new programming technique.

5.0 SUMMARY

In this unit you have had a comparison of pro-ramming techniques and I am sure you now know why object oriented programming technique stands shoulder high

6.0 TUTOR MARKED ASSIGNMENT

Describe the four programming techniques discussed in this unit.

7.0 REFERENCES/FURTHER READING

Peter Muller - introduction to Object Oriented Programming in C++ Globe wide Network Academy (GNA)

MODULE 2 OBJECT-ORIENTED ANALYSIS AND DESIGN

UNIT 1 SOFTWARE ENGINEERING

CONTENTS

1.0 INTRODUCTION

This unit focuses on Software Product, Component and Characteristics. This unit discusses in details the evolution process of Software Engineering life cycle. A sample waterfall model is also discussed in this unit. Software Engineering concepts and its phases are also included in this unit. The documentation part is also included in this unit, Software Documentation is a continuous and parallel activity in development process.

2.0 OBJECTIVES

After going through this unit, you should be able to:

- define software product component and characteristics.
- explain what is documentation of software product.
- describe what is software process and what is software life cycle.
- describe a generic view of software engineering.

3.0 MAIN CONTENT

3.1 Software Product, Components and Characteristics

We are in an information age, one in which the management of the information resource of organization is of vital importance. Business information systems are systems that use these resources to convert data into information in order to improve productivity. Business information systems usually are composed of smaller systems, called subsystems. Computer hardware and software are important resources that that support information systems and subsystems.

Systems analysis is a general terms that refers to an orderly, structured process life cycle-methodology. Four phases - study, design, development, and operation - make up the life -cycle of computer-related business systems. A systems analyst is a person who performs systems analysis during any or all of the life-cycle phases. The systems analyst not only analyzes information system problems, but also synthesizes new systems to solve these problems.

The four information eras are: the Early Era (1940-1955), the Growing Era (1995- 1965), the Refining Era (1965-1980), and the Maturing Era (1980-). The Early Era concentrated on hardware, and human machine communication was very difficult. The growing Era improved this communication through the introduction of English- like programming languages; however, techniques for managing Computer related projects were lacking. During the Refining Era, explosive growth occurred in the development of large (midi and maxi) and small (micro and mini) computer systems and in their applications. Developments in microelectronics technology contributed significantly to this growth. Throughout most of the Refining Era, in spite of a proliferation of applications, difficulties were encountered in using computer to solve business problems. However, toward the end of this era, a structured system analysis process-called the life-cycle methodology - came into increasing use as a means of developing usable business information systems. Structured techniques for the analysis, design, and development of computer-related information systems are now

enhanced in the maturing Era. These techniques are used to develop information systems in applications areas such as distributed, data processing, the automated office, and management-decision support. This is an era in which information is acknowledged as an important corporate resource. The systems analyst assumes an important role in managing the information resources of the corporation.

The computer-based business system also contains hardware components; however, its most significant characteristics is a software end-product. Software may be defined as a collection of programs or routines that facilitates the use of a computer. This definition includes operating systems, which facilitate the general use of computers, and application programs, which are written to solve specific problems. The latter is the end-product associated with a computer-based information system. Software, in contrast with hardware, does not possess attributes that can readily be observed and measured from concept to end product. The software end-product is information. Although it may be stored or printed on a physical medium, such as a magnetic disk, a reel of tape, or a sheet of paper, information is transient and fragile compared with hardware.

Many of the past difficulties in developing effective computer-based business systems stemmed not only from belated efforts to apply management controls, but also from failure to recognize that techniques applicable to the development of hardware end-products could not be applied without modification to the development of software end-products. However, as a result of experience gained from large government and commercial software projects in the latter part of the 1960s and throughout the 1970s, the concept of life-cycle management was adapted to fit the development of computer based business systems.

The key to modifying the life-cycle concept for the management of software projects was the recognition that, although supporting documentation accompanies a physical product throughout its development, documentation is the software product.

TOOLS
METHODS
PROCESS
QUALITY

Figure 1.1: Software engineering layers

3.2 Software Engineering Phases

Life-Cycle Phases and the Life-Cycle Manager:

The life-cycle methodology for developing complex systems is modular, top-down procedure. In the study phases, modules that describe the major functions to be performed by the system are developed. The procedure is called top-down because in successive phases the major modules are expanded into additional, increasingly detailed, modules. Powerful graphic tools have been developed to structure the top-down design and development phase activities in detail. For the present, we can summarize the principal tasks associated with each of the phases of the life cycle of a computer-based business system.

The life cycle of a computer-based system exhibits distinct phases. These are:

3.2.1 The Study Phase

This is the phases during which a problem is identified, alternate system required to design the system. Task performed in the study phase are grossly analogous to determining that a shelter from the elements is needed, and deciding that a two-bedroom house is a more appropriate shelter than a palace, a cave, or other possible selections.

3.2.2 The Design Phase

In this phase the detailed design of the system selected in the study phases is accomplished . this is analogous to drawing the plans for the two-bedroom home decided on in the study phase. In the case of a computer-based business system, design phase activities include the allocation of resources to equipment tasks, personnel tasks, and computer program task. In the design phase, the technical specifications are prepared for the performance of all allocated tasks.

3.2.3 The Development Phase

This is the phase in which the computer-based system is constructed from the development phase. All necessary procedure, manuals, software specifications, and other documentation are completed. The staff is trained, and the complete system is tested for operational readiness. This is analogous to the actual construction of our two-bedroom house from the plans prepared in its design phase.

3.2.4 The Operation Phase

In this phase, the new system is installed or there is a changeover from the old system to the new system. The new system is operated and maintained. Its performance is reviewed, and changes in it are managed, the operation phase is analogous to moving into and living in the house that we have built. If we have performed the activities of the preceding phases adequately, the roof should not leak.

All of the activities associated with each life-cycle phase must be performed, managed, and documented. Hence, we now define systems analysis as the performance, management, and documentation of the activities related to the four life-cycle phases of a computer based business system. Similarly, we now can identify the system analyst as the individual who is responsible for the performance of systems analysis for all, or a portion of the phases of the life cycle of a business system. The analyst is, in effect, a lifecycle manger.

3.3 Documentation of the Software Product

The accumulation of documentation parallels the life-cycle performance and management review activities. Documentation is not a task accomplished as a "wind up" activity; rather, it is continuous and cumulative. The most essential documents are called baseline specification (that is, specifications to which change can be referred). There are three baseline specifications:

1. Performance specification: It is completed at the end of the study phase, and describing in the language of the user exactly what the system is to do. It is a "design to" specification.

2. Design specification: It is completed at the end of the design phase, and describing in the language of the programmer (and others employed in actually constructing the system) how to develop the system. It is a "but to".
3. System specification: It is completed at the end of the development phase and containing all of the critical system documentation. It is the basis for all manuals and procedures, and it is an "as built" specification.

The design specification evolves from the performance specification, and the system specification evolves from the design specification. Since these documents are the only measurable evidence that progress is being made toward the creation of a useful software end-product, it is not possible to manage the lifecycle process without them. Thus, documentation is not only the "visible" software end-product, but also

the key to the successful management of the life cycle of computer-based business systems.

SELF-ASSESSMENT EXERCISE 1

Which of the following is not an example of program documentation?

(a) Source code
(b) Object code
(c) Specification
(d) Identifier Names

3.4 Software Process And Models

3.4.1 Software Life Cycle

From the inception of an idea for a software system, until it is implemented and delivered to a customer, and even after that, the system undergoes gradual development and evolution. The software is said to have a life cycle composed of several phases. Most of these phases result in the development of either a part of the system or something associated with the system, such as a test plan or user manual. In the traditional life cycle model, called the "waterfall model," each phases has well-defined starting "and ending points, with clearly identifiable deliverables to the next phase.

A sample waterfall life cycle model comprises the phases, similar to described in next sections.

3.4.2 Requirements analysis and specification

Requirements analysis is usually the first phase of large-scale software development project. It is undertaken after a feasibility study has been performed to define the precise costs and benefits of a software system. The purpose of this phase is to identify and document the exact requirements for the system. The customer, the developer, a marketing organization or any combination of the three may perform such study. In cases where the requirements are not clear e.g., for a system that has never been defined, more interaction is required between the user and the developer. The requirements at this stage are in end-user terms. Various software engineering methodologies advocate that this phase must also produce user manuals and system test plans.

3.4.3 Design and specification

Once the requirements for a system have been documented, software engineers design a software system to meet them. This phase is sometime split into two sub-phases: architectural or high-level design and detailed design. High-level design deals with overall module structure and organization, rather than the details of the modules. The high level design is refined by designing each module in detail (detailed design). Separating the requirements analysis phase from the design phase is instance of a fundamental "what/how" dichotomy that we encounter quite often in computer science. The general principle involves makings a clear - distinction between what the problem is and how to solve the problem. In this case, the requirement phase attempts to specify what the problem is. There are usually many ways that the requirements may be met, including some solutions that do not involve the use of computers at all. The purpose of the design phase is to specify a particular software system that will meet the stated requirements. Again there are usually many ways to build the specified system. In the coding phase, which follows the design phase, a particular system is coded to meet the design specification.

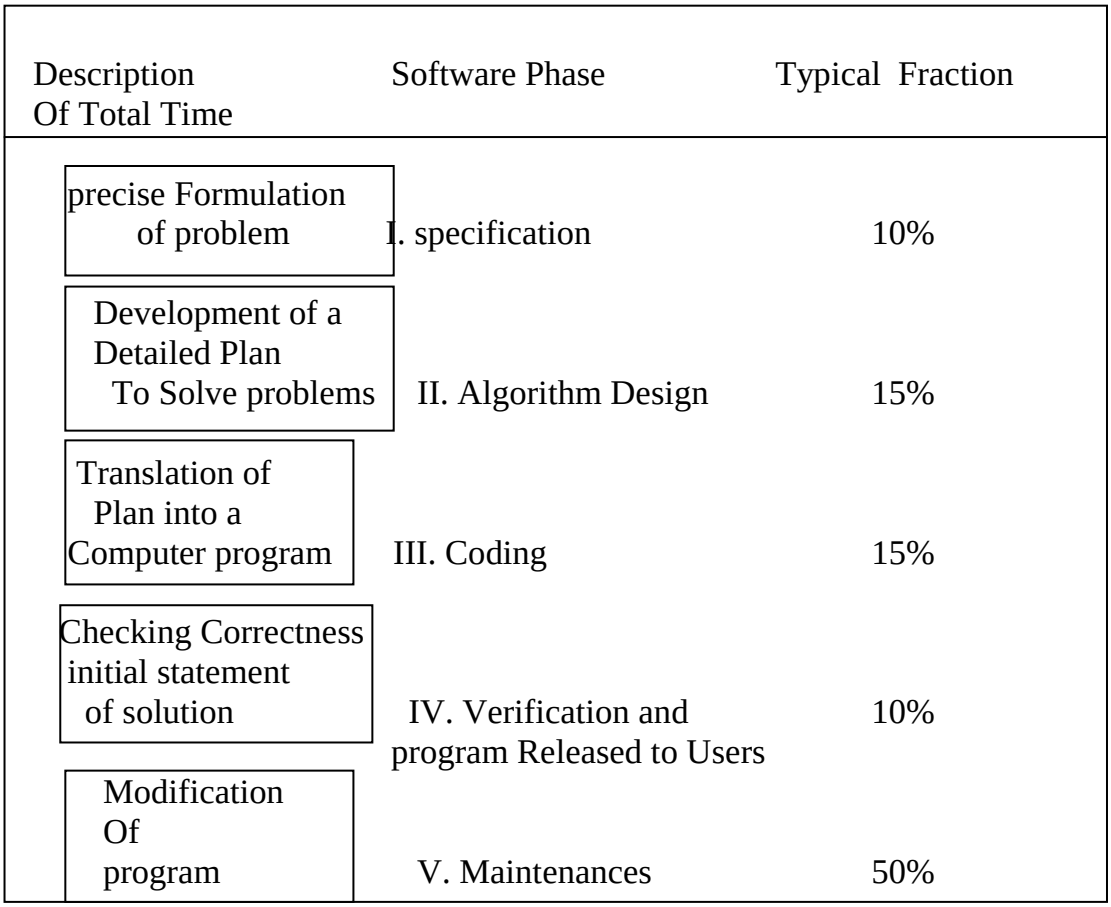


Figure 1.2: Software Life Cycle

3.4.4 Coding and module testing

This is the phase that produces the actual code that will be delivered to the customer as the running system. The other phases of the life cycle may also develop code, such as prototypes, tests, and test drivers, but these are for use by the developer. Individual modules developed in this phase are also tested before being delivered to the next phase.

- Integration and system testing: All the modules that have been developed before and tested individually are put together (integrated) in this phase and tested as a whole system.

- Delivery and maintenance: Once the system passes the entire test, it is delivered to the customer and enters the maintenance phase. Any modifications made to the system after initial delivery are usually attributed to this phase.

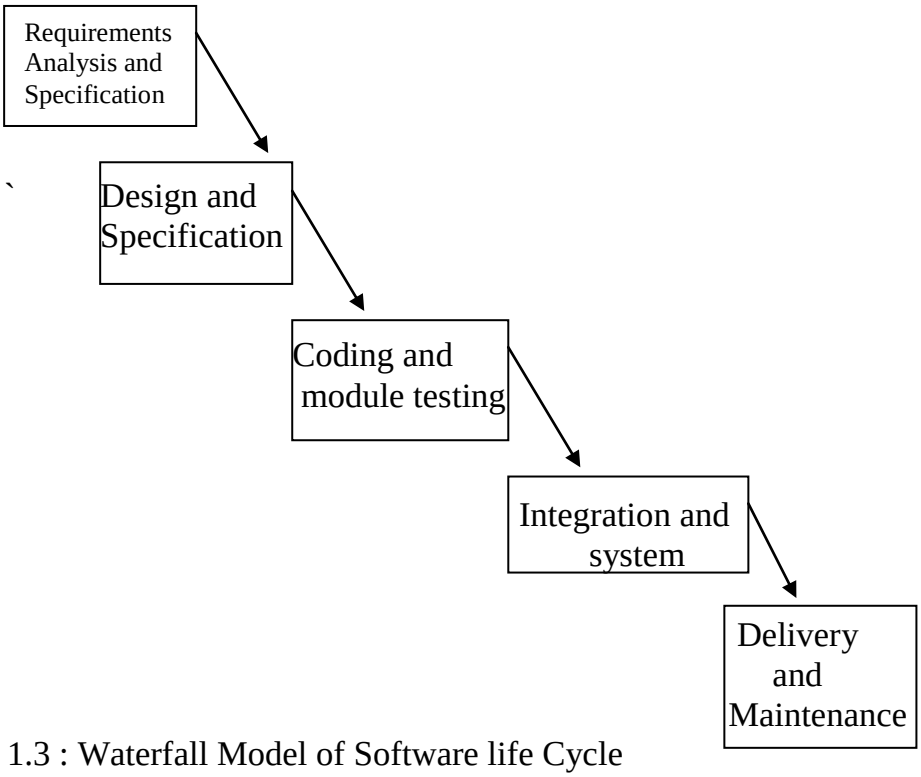


Figure 1.3 : Waterfall Model of Software life Cycle

SELF-ASSESSMENT EXERCISE 2

Which of the following is (are) among the legitimate purposes of software documentation?

i. To assist in maintaining and modification.
ii. To describe the capabilities of the program.
iii. To provide the user with instructions.

a) ii only
b) ii and iii only
c) iii only
d) i, ii and iii

4.0 CONCLUSION

As presented above, the phases give a partial, simplified view of the conventional waterfall software life cycle. The process may be decomposed into a different set of phases, with different names, different purpose, and different granularity. Entirely different life cycle schemes may even be proposed, not based on a strictly phased waterfall development. For example, it is clear that if any tests uncover defects in the system, we have to go back at least to the coding phase and perhaps to the design phase to correct some mistakes. In general, any phase may uncover problems in previous phases this will necessitate going back to the previous phases and redoing some earlier work. For example, if the system design phase uncovers inconsistencies or ambiguities in the system requirements, the requirements analysis phase must be revisited to determine what requirements were really intended.

Another simplification in the above presentation is that it assumes that a phase is completed before the next one begins. In practice, it is often expedient to start a phase before a previous one is finished. This may happen, for example, if some data necessary for the completion of the requirement phase will not be available for some time or it might be necessary because the people ready to start the next phases are available and have nothing else to do.

Most books on software engineering are organized according to the traditional software life cycle model, each, section or chapter being devoted to one phase. Once mastered, the software engineer can apply these principles in all phases of software development, and also in life cycle models that are not based on phased development, as discussed above. Indeed, research and experience over the past decade have shown that there is a variety of life cycle models and that no single one is appropriate for all software systems.

5.0 SUMMARY

In this unit, you have learnt the techniques applicable to the development of software products. The phases of software engineering and the use of baseline specifications in the software process were also discussed. The next unit focuses on Software Performance.

6.0 TUTOR-MARKED ASSIGNMENT

1. The life cycle of a computer-based system exhibits distinct phases. Discuss
2. Describe the phases of a Software Life Cycle

7.0 REFERENCES/FURTHER READING

Management of Information Systems, Unit 2, Indira Gandhi National Open University

Software Engineering - A Practitioner's Approach by ROGER S.PRESSMAN: McGraw Hill International Edition.

UNIT 2 SOFTWARE QUALITY CONCEPTS

CONTENTS

1.0 INTRODUCTION

The goal of any engineering activity is to build a product. For example, the aerospace engineer builds an airplane. The product of software engineer is a software system. But the difference between software product and other product is that it is modifiable. This quality makes software quite different from other products such as cars. In this unit, we will first examine the important software qualities and then discuss software engineering principles.

2.0 OBJECTIVES

After going through this unit, you will be able to:

- list various qualities of software product
- discuss various qualities of software product
- explain principles of software engineering.

3.0 MAIN CONTENT

3.1 Important Qualities of Software Product and Process

There are many important qualities of software products. Some of these qualities are applicable both to product and to the process used to produce the product.

The user wants the software product to be reliable and user-friendly. The designer of the software wants it to be maintainable portable and extensible. In this unit, we will consider all these qualities.

3.1.1 Correctness

A program is functionally correct if it behaves according to the specification of function it should provides (called functional requirements specifications). It is common simply to use the term correct rather the functionally correct, similarly, in this context, the term specification implies functional requirement specifications. We will follow this convention when the context is clear.

The definition of correctness assumes that a specification of the system is available and that it is possible to determine unambiguously whether or not a program meets the specifications. With most current software systems, no such specification exists. If a specification does exists, it is usually written in an informal style using natural language. Such a specification is likely to contain many ambiguities. Regardless of these difficulties with current specifications, however, the definition of correctness is useful. Clearly, correctness is a desirable property for software systems.

Correctness is a mathematical property that establishes the equivalence between the software and its specification. Obviously, we can be more systematic and precise in assessing correctness depending on how rigorous we are in specifying functional requirements. Correctness can be assessed through a variety of functional requirements. Correctness can be assessed trough a variety of methods, some stressing an experimental approach (e. g testing). others stressing an analytic

approach (e.g. formal verification of correctness). Correctness can also be enhanced by using appropriate tools such as high-level languages, particularly those supporting extensive static analysis. Likewise, it can be improved by using standard algorithms or using libraries of standard modules, rather than inventing new ones.

3.1.2 Reliability

Informally, software is reliable if the user can depend on it. The specialized literature on software reliability defines reliability in terms of statistical behaviour the probability that the software will operate as expected over a specified time interval.

Correctness is an absolute quality; any deviation from the requirements makes the systems incorrect, regardless of how minor or serious is the consequences of the deviation. The notion of reliability is on the other hand, releases along with a list of know bugs. User of software takes it for granted that Release I of a product is buggy. This is one of the most striking symptoms of the immaturity of the software engineering field as an engineering discipline.

In classic engineering disciplines, a product is not released if it has bugs. You do not expect to take delivery of an automobile, along with a list of shortcomings or a bridge with a warning not to use the railing. Design errors are extremely rare and worthy of news headlines. A bridge that collapses may even cause the designers to be prosecuted in court.

On the contrary, software design errors are generally treated as unavoidable. Far from being surprised with the occurrence of software errors, we expect them. Whereas with all other products the customers receives a guarantee of reliability, with software we get a disclaimer that the software manufacturer is not responsible for any damage due to product errors. Software engineering can truly be called an engineering discipline only when we can achieve software reliability comparable to the reliability of other products.

3.1.3 Robustness

A program is robust if it behaves reasonably, even in circumstances that were not anticipated in the requirements specification - for example, when it encounters incorrect input data or some hardware malfunction. A program that assumes perfect input and generates as unrecoverable run-time error as soon as the user inadvertently type an incorrect command would not be robust. It might be correct, though, if the requirements specification does not state what the action should be upon entry of an incorrect command. Obviously, robustness is a difficult to

define quality; after all, if we could state precisely what we should do to make an application robust, we would be able to specify its reasonable behaviour completely. Thus, robustness would become equivalent to correctness.

The amount of code devoted to robustness depends on the application area For example, a system written to be used by novice computer users must be more prepared to deal with ill-formatted input than an embedded system that receives its input from a sensor - although, if the embedded system is controlling the space shuttle or some life-critical devices, then extra robustness is advisable.

In conclusion, we can see that robustness and correctness are strongly related without a sharp dividing line between them. If we put a requirement in the specification, its accomplishment becomes an issue of correctness; if we leave it out of the specification, it may become an issue of robustness. The borderline between the two qualities is the specification of the system. Finally, reliability comes in because not all incorrect behaviours signify equally serious problems; some incorrect behaviours may actually be tolerated.

Correctness, robustness, and reliability also apply to the software production process. A process is robust, for example, if it can accommodate unanticipated changes in the environment, such as a new release of the operating system of the sudden transfer of half the employees to another location. A process is reliable if it consistently leads to the production of high-quality products. In many engineering disciplines, considerable research is devoted to the discovery of reliable processes.

3.1.4 User Friendliness

A software system is user friendly if its human user find it to use. This definition reflects the subjective nature of user friendness. An application that is used by novice programmers qualifies a user friendly by virtue of different properties than an application that is used by expert programmers. For example, a voice user may appreciate verbose messages, while an experienced user grows to dates and ignore them. Similarly, a nonprogrammer may appreciate the use of menus, while a programmer may be more comfortable with typing a command.

The **user interface** is a important component of user friendliness. A software system that present the novice user a set of one-letter commands is not user friendly. On the other hand, a keystrokes rather than a fancy widow interface through which he has to navigate to get to

the command that's he knew all along he wanted to execute, will not be appropriate.

There is more to user friendliness, however, than the user interface. For example, an embedded software system does not have a human user interface. Instead, it interacts with hardware and perhaps other software systems. In this case, the user friendliness is reflected in the case with which the system can be configured and adapted to the hardware environment.

In general, the user friendliness of a system depends on the consistency of its user and operator interfaces. Clearly, however, the other qualities mentioned above such as correctness and performance - also affect user friendliness. A software system that produces wrong answers is not friendly, regardless of how fancy it user interface is. Also, a software system that produces answers more slowly than the user requires is not friendly even if the answers are displayed in colour.

User friendliness is also discussed under the subject human factors. Human factors or human engineering plays a major role in many engineering disciplines. For example. automobile manufacturers devote significant effort to deciding the position of the various control knobs on the dashboard. Television manufacturers and microwave oven makers also try to make their products easy to use. User interface decisions in these classical engineering fields are made, not randomly by engineers, but only after extensive study of user needs and attitude by specialists in fields such as industrial design or psychology.

Interestingly, ease of use in many of these engineering disciplines is achieved through standardization of the human interface. One set, he or she can operate almost any other television set. The significant current research and development activity in the area of standard user interface for software systems will lead to more user-friendly systems in future.

3.1.5 Verifiability

A software system is verifiable if its properties can be verified easily. For example, the correctness or the performance of a software system are properties we would be interested in verifying. Verification can be performed either by formal analysis methods or through testing. A common technique for improving verifiability is the qualities such as performance or correctness.

Modular design, disciplined coding practices, and the use of a appropriate programming language all contribute to verifiability.

Verifiability is usually an internal quality, although it sometimes becomes an external quality also. For example, in many security-critical applications, the customer requires the verifiability of certain properties. The highest level of the security standard for a trusted computer system requires the verifiability of the operation system kernel.

3.1.6 Maintainability

The term **software maintenance** is commonly used to refer to the modification that are made to a software system its initial release. Maintenance used to be viewed as merely bug fixing, and it was distressing to discover that so much effort was being open on fixing defects. Studies have shown, however, that the majority of time spent on maintenance is in fact spent on enhancing the product with features that were not in the original specifications or were stated incorrectly.

Maintenance is indeed not the proper word to use with software. First, as it is used today, the terms cover a wide range of activities, all having to do with modifying an existing piece of software in order to make an improvement. A term that perhaps captures the essences of this process better is software evolution. Second, I other engineering products, such as computer hardware or automobiles or washing machine, maintenance refers to the upkeep of the product in response to the gradual deterioration of parts due to extended use of the product. For example, transmissions are oiled and air filters are dusted and periodically changes. To use the word maintenance with software gives the wrong connotation because software does not wear out. Unfortunately, however, the term is used so widely that we will continue using it.

There is evidence that maintenance costs exceed 60% of the total cost of software. To analyze the factor that affect such costs, it is customary to divide software maintenance into three categories, corrective, adaptive and perceptive maintenance.

3.1.7 Reusability

Reusability is akin to resolvability. In product evolution, we modify a product to build a new version of that same product. Reusability appears to be more applicable to software components than to whole product. But it certainly seems possible to build products that are reusable

A good example of a reusable product is the UNIX shell. The UNIX shell is a command language to be used both interactively and in batch. The ability to start a new shell with a file containing a list of shell commands allows us to write program scripts - in the shell command language. We can view the program as a new product that uses the shell

as a component. The UNIX environment in fact supports the reuse of any of its commands, as well as the shell, in building powerful utilities.

Scientific libraries are best known reusable components. Several large FORTRAN libraries have existed for many years. User can buy these and use them to build their own products, without having to reinvent or recode well-know algorithms. Indeed, several companies are devoted to producing just such libraries.

Another successful example of reusable packages is the recent development of windowing system such as Microsoft Window, X windows or Motif, for the development of user interface.

Unfortunately, while reusability is clearly an important tool for reducing software production costs, example of software reuse in practice is rather rare.

Reusability is difficult to achieve a posteriori, therefore, one should strive for reusability when software components are developed. One of the more promising techniques is the use of object-oriented design, which can unify the qualities of resolvability and reusability.

So far. We have discussed reusability in the framework of reusable components, but the concept has boarder applicability it may occur at different levels and may affect both product and process. A simple and widely practiced type of reusability consists of the reuse of people, i.e. reusing their specific knowledge of an application domain of a development or target environment, and so on. This level is unsatisfactory, partially due to the turnover of software engineers: knowledge goes away with people and never becomes a permanent asset.

Another level of reuse may occur at the requirements level. When a new application is conceived, we may try to identify parts that are similar to parts used in a previous application. Thus, we may reuse parts of the previous requirement specification instead of developing an entirely new one.

As discussed above, further levels of reuse may occur when the application is designed, or even at the code level. In the latter case, we might be provided with expect claim that in the future new application by assembling together a set ready-made, off- the- shell component. Software companies will invest in the development of their own catalogues of reusable components so that the knowledge acquired in developing applications will not disappear as people leave, but will progressively accumulate in the catalogues. Other companies will invest

their efforts in the production of generalized reusable components to be put on the marketplace for use other software producers.

Reusability applies to the software process as well. Indeed, the various software methodologies can be viewed as attempts to reuse the same process for building different products. The various life cycle models are also attempts at reusing higher level processes. Another example of reusability in a process is the replay approach to software maintenance. In this approach, the entire process is repeated when making a modification. That is, first the requirements are modified, and then the subsequent steps are followed as in initial product development.

Reusability is a key factor that characterizes the maturity of an industrial field.We see high degrees of reusability in such mature areas as the automobile industry and consumer electronic. For example, in the automobiles industry, the engines often reused from model to model. Moreover, a car is constructed by assembling together many components that are highly standardized and used across many models produced by the same industry. Finally, the manufacturing process is often reused. The low degree of reusability in software is a clear indication that the field must evolve to achieve the status of a well established discipline.

3.1.8 Portability

Software is portable if it can run is different environments. The term environment can refer to a hardware platform or a software environment such as a particular operating system. With the proliferation of different processors and operating systems, portability has become an important issue for software engineers.

More generally, portability refers to the ability to run a system on different hardware platforms. As the ratio of money spent on software versus hardware increase, portability gains more importance. Some software systems are inherently machine specific. For example, an operating system is written to control a specific computer, and a compiler produces code for a specific machine. Even in these cases, however, it is a possibility to achieve some level of portability. Again, UNIX is an example of an operating system that has been ported to many different hardware systems. Of course, the porting effort requires months of work. Still, we can call the software portable because writing the system from scratch for the new environment would require much effort than porting it.

For many applications, it is important to be portable across operating system. or, looked at another way, the operating system provides portability across hardware platforms.

3.2 Data abstraction

Abstraction is a process whereby we identify the important aspects of a phenomenon and ignore its details. Thus, abstraction is a special case of separation of concerns wherein we separate the concern of the important aspects from the concern of the unimportant details.

The programming language that we use are abstraction built on top of the hardware: they provide us with useful and powerful constructs so that we can write (most) programs ignoring such details as the number of bits that are used to represent numbers or the addressing mechanism. This helps us concentrate on the problem to solve rather than the way to instruct the machine on how to solve it. The programs we write are themselves abstractions. For example, a computerized payroll procedure is an abstraction over the manual procedure it replaces: it provides the essence of the manual procedure, not its exact details, well defined procedure/ function in a single unit. This encapsulation forms a wall, which is intended to shield the data representation from computer users. There are two requirements for data abstraction facilities in programming language.

(1) Data structure and operations as described is a single semantic unit.

(ii) Data structure and internal representation of the data abstractions are not visible to the programmer. rather the programmer is presented with a well defined procedural interface. Today most of the object oriented programming language supports this feature.

3.2.1 Modularity

A complex system may be divided into similar pieces called modules. A system that is composed of modules is called modular. The main benefit of modularity is that it allows the principle of separation of concerns to be applied in two phases: when dealing with the details of each module in isolation (and ignoring details of other modules); and when dealing with the overall characteristics of all modules and their relationship in order to integrate them into a coherent system. If the two phases are temporarily executed in the order mentioned, then we say that the systern is designed bottom up; the converse denotes top-down design.

Modularity is an important property of most engineering processes and products. For example, in the automobiles industry, the construction of cars proceeds by assembling building blocks that are designed and built separately. Furthermore, parts are often reused from model to model, perhaps after minors changes. Most industrial processes are essentially modular, made out of work packages that are combined in simple ways (sequentially or overlapping) to achieve the desired result.

Modularity, however, is not only a desirable design principle, but permeates the whole of software production. In particular, there are three goals that modularity tries to achieve in practice: capacity of decomposing a complex system or composing it from existing modules, and of understanding the system in pieces.

The decomposability of a system is based on dividing the original problem top down into sub problems and then applying the decomposition to each sub problem recursively. This procedure reflects the well - known Latin motto divide (divide and conquer), which described the philosophy followed by the ancient Romans to dominate other nations: divide and isolate them first and conquer them individually.

The compensability of a system is based on starting bottom up from elementary components and proceeding to the finished system. As an example, a system for office automation may be designed by assembling together existing hardware components such as personal workstation, a network, and peripherals: system software such as the operating system; and productivity tools such as document processors, data bases and spreadsheets. A car is another obvious example of a system that is built by assembling components. Consider first the main subsystems in a car system, each of them, in turn, is made out of standard parts, for example, the battery, fuses, cables, etc. form the electrical system. When something goes wrong, defective components maybe replaced by new ones.

Ideally, in software production we would like to be able to assemble new applications by taking modules from a library and combining them to form the required product. Such modules should be designed with the express goal of being reusable. By using reusable components, we may speed up both the initial system construction and its fine-tuning. For example, it would be possible to replace a component by another that perform s the same function but differs in computational resource requirements.

The capability of understanding each part of a system separately aids in modifying a system.The evolutionary nature of software is such that the

software engineer is often required to go back to previous work to modify it. If the entire system can be understood only entirely, modifications are likely to be difficult to apply, and the result unreliable. When the need for repair arises, proper modularity helps confine the searches for the source of malfunction to single components.

To achieve modular compensability, decomposability, and understanding, modules must have high cohesion and low coupling.

A module has high cohesion if all elements are related strongly. Elements of a module (e.g. statement, procedures, and declarations) are grouped together in the same modules for a logical reason, not just by chance; they co-operate in the same modules (e. g. modules A call a routine provided by module B or

accesses a variable declared by Module B) if two modules in a system to exhibit low coupling, because if two modules are highly coupled, it will be difficult to analyze, understand, modify, test, or reuse them separately.
Module structures with high cohesion and low coupling allow us to see modules as black boxes when the overall structure of a system is described and then deal with each module separately when the module's functionality is described or analyzed. This is just another example of the principle of separation of concerns.

3.2.2 Principles Of Software Engineering

Engineering disciplines have principles based on the laws of physics, biology, chemistry or mathematics. Principles are rules to live by, they represent the collected wisdom of many dozens of people who have learned through experience.

Because the product of software engineering is not physical, physical laws do not form a suitable foundation. Instead, software engineering has had to evolve its principles based solely on observation of thousands of projects. The following are probably the more important ones. A customer will not tolerate a poor-quality product, regardless of how you define quality. Quality must be quantified and mechanisms put into to deliver a product on time, even though its quality is poor, but this is correct only in the short term, it is suicide in the middle and long term. There is no trade-off to be made here. The first requirement must be quality.

However, there is no one definition of software quality. To developers, it might be elegant design or elegant code. To users, it might be good response time or high customers, it might be satisfying all their

perceived and no-yet-perceived needs. The dilemma is that these definitions may not be compatible.

3.2.3 High-quality Software Possible

Although our industry is saturated with examples of software system that perform poorly, are full of bugs, or otherwise fail to satisfy user needs, there are counter example. Large software systems can be built with very high quality, but they carry a steep price tag - on the order of $1,000 per line of code: one example is IBM's on-bard flight software for the space shuttle: three million lines of code with less than one error per 10,000 lines.

Techniques that have been demonstrated to increase quality considerably include involving the customer, prototyping (to verify requirements before full-scale development), simplifying design, conducting inspections, and hiring the best people.

3.2.4 Give Products to Customers Early

No matter how hard you try to learn user's needs during the requirements phase, the most effective way to ascertain real needs is to give users a product and let them play with it. The conventional waterfall model delivers the first product after 99 percent of the development resources have been expanded. Thus, the majority of customer feedback on need occurs after resource have been expanded. Contrast this with an approach that you deliver a quick - and dirty prototype early in development, gather feedback, write a requirements specification, and then proceed with full-scale development. In this scenario, only five to twenty percent of development resources have been expended when customers first see the product.

3.2.5 Evaluate Design Alternatives

After the requirements are a-reed upon. you must examine a variety of architectures and algorithms. You certainly do not want to use an architecture simply because it was used in the requirements specification. After all, that architecture was selected to optimize the Understandability of the system's external behaviour. The architecture you want is the one that optimizes conformance with the requirements.

For example, architectures are generally selected to optimize constructability, throughput, response time, modifiability, portability, interoperability, safety, functional requirements. The best way to do this is to enumerate a variety of software architectures, analyze (or simulate) each with respect to the goals, and select the best alternative. Some

design methods result in specific architectures, so one way to generate a variety of architectures is to use a variety of methods.

3.2.6 Use an Appropriate Process Model

There are dozens of process model: waterfall, throwaway prototyping, incremental, spiral, operational prototyping, and so on. There is no such thing as process model that works for every project,. Each project must select a process that take risks, application area, volatility of requirements, and the extent to which requirements are well-understood.

Study your project's characteristics and select a process model that makes the most sense. When building a prototypes for example, choose a process that minimizes protocol, facilitates rapid development and does not worry about checks and balances. Choose the opposite when building a file critical product.

3.2.7 Minimize Intellectual Distance

Edsger Dijkstra defined intellectual distance as the distance between the real-world problem and the computerized solution to the problem. Richard Fairley has argued that the smaller the intellectual distance, the easier it is to maintain the software. To minimize intellectual distance, the software's structure should be as close as possible to the real-world structure. This is primary motivation for approaches such as objective-oriented design and Jackson System Development. But you can minimize intellectual distance using any design approach. Of course, the real -world structure can vary as Jawed Siddigni points out (Challenging University Truths of Requirements Engineering, Mar, 1994, pp.1819). Different humans perceive different structures when they examine the same real world and this construct quite different realities.

3.2.8 Good Management is More Important than Good Technology

The best technology will not compensate for poor management, and a good manager can produce great results even with meager resources. Successful software start -ups are not successful because they have great process of great tools (or great products for that matter!). Most are successful because of great management and great marketing.

Good management motivates people to do their best, but there are no universal right styles of management. Management style must be adapted to the situation. It is not uncommon for a successful leader to be

an autocrat in one situation and a consensus based leader in another. Some styles are innate, others can be learnt.

3.2.9 People are the key to success

Highly skilled people with appropriate experience, talent and training are key. The right people with insufficient tools, languages, and process will succeed. The wrong people with appropriate tool, language and process will probably fail (as will the right people with insufficient training or experience). When interviewing prospective employees, remember that there is no substitute for quality. Don't compare two people by saying, person x is better than person y but person y good enough and less expensive. Your can't have all superstars, but unless you truly have an overabundance, hire them when you find them!

3.2.10 Follow with care

Just because everybody is doing something does not make it right for you. It may be right, but you must carefully assess its applicability to you environment. Object orientation, measurement, reuse, process improvement, CASE, prototyping - all these, might increase quality, decrease cost, and increase user satisfaction.

However, only those organizations that can take advantage of them will reap the rewards. The potential of such techniques is often oversold, and benefits are by no means guaranteed or universal. You can't afford to ignore a new technology. But don't believe the inevitable hype associated with it. Read carefully. Be realistic with respect to payoffs and risks. And run experiments before you make a major commitment.

3.2.11 Take responsibility

When a bridge collapses we ask, **what did the engineers do wrong?** When software fails we rarely ask this. When we do, the response is, **I was just following the 15 steps** of this method, or My manager made me do it or The Schedule left insufficient time to do it right. The fact is that in any engineering discipline the best methods can be used to produce awful designs, and the most antiquated methods to produce elegant designs.

There are no excuses: If you develop a system, it is your responsibility to do it right. Take that responsibility. **Do it right, or don't do it at all.**

4.0 CONCLUSION

Software engineering deals with the applications of engineering principles to the blinding of software products. The arrive at a set of engineering principles, one has to select a set of qualities that characterize the products. In this unit we presented a set of' qualities for software product. At the end, we discussed several principles which should be applied in designing software products that achieve these qualities.

5.0 SUMMARY

In this unit you have learned about qualities to consider in software products and processes. You have also learnt about Software Engineering principles. In the next unit you will learn about issues that relate to software performance.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss seven (7) of the important qualities of software products
2. Outline the principles of Software Engineering discussed in this unit.

7.0 REFERENCES/FURTHER READING

Management of Information Systems, Unit 2, Indira Gandhi National Open University

Software Engineering - A Practitioner's Approach by ROGER S.PRESSMAN: McGraw Hill International Edition.

UNIT 3 LANDMARKS OF OBJECT-ORIENTED ANALYSIS AND DESIGN

CONTENTS

1.0 INTRODUCTION

Like many other concepts. The object-oriented concept did not come up overnight. Object-oriented design has come a long way. In this unit, some of the important landmarks of` object-oriented design will be discussed.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the origin of Object-oriented design
- differentiate between the two cultures in the "object-oriented community"

3.0 MAIN CONTENT

3.1 Origin of Object-Oriented Design

Work on what was to become "structured design" began in the early 1960s. Structured design, as a well defined and named concept, did not achieve appreciable visibility until the publication of an article in the IBM Systems Journal in 1974. Five years later, Prentice Hall published a book by Larry Constantine and Edward Yourdon that introduced structured design to the masses.

Even before 1979, variations on Constantine's version of structured design began to appear. After 1979, software engineers could select from an ever increasing variety of approaches to structured design, e.g., Gomaa, 1984], Ward and Mellor. 1985], [Hatley and Pirbliai, 1987], and [Marca and McGowan, 1988]. It should be obvious to even a casual observer that there is more than one way to accomplish a "structured design."

Like structured design, the term "object-oriented design" (OOD) means different things to different people. For example, OOD has been used to imply such things as:

- The design of individual objects, and/or the design of the individual methods contained in those objects
- the design of an inheritance (specialization) hierarchy of objects,
- the design of a library of reusable objects , and
- the process of specifying and coding of an entire object-oriented application.

What many people consider to be the first object-oriented programming language - Similar - was introduced in 1966. The term "object-oriented," however, did not come into use until around 1970, with many people crediting Alan Kay as the person who coined the term.

3.2 Two Different Cultures

Part of the problem is the diversity within the so-called "object-oriented community." Many object oriented people seem to focus primarily on programming language issues. They tend to cast all discussions in terms of the syntax and semantics of their chosen object-oriented programming language. These people find it almost impossible to discuss any software engineering activity (e.g_ analysis, design, and testing) without direct mention of some specific implementation language.

Outside of producing executable "prototypes," people who emphasize programming languages seldom have well-defined techniques for analyzing their client's problems or describing the overall architecture of the software product. A great deal of what they do is intuitive. If they have a natural instinct/intuition for good analysis or good design, their efforts on small-to-medium, non-critical projects can result in respectable software solutions.

Programming language people use the terms "analysis" and "design" in a very loose sense. Analysis can mean listening to their customer, making some notes and sketches, thinking about both the problem and potential solutions, and even constructing a few software prototypes. Design can mean the code-level design of an individual object, the development of an inheritance (specialization) hierarchy, or the informal definition and implementation of a software product (e.g., identify all the objects, create instances of the objects, and have the instances send messages to each other).

Another group of object-oriented people are interested in formality and rigor. To these people, software engineering is largely very systematic, repeatable, and transferable. They view object-oriented software engineering as primarily an engineering process with well-defined, coordinated tasks, and well-defined deliverables. The quality of the resulting products (and the process itself) can be evaluated in a quantitative, as well as qualitative, manner.

For members of this second camp, "object-oriented programming" (OOP) is primarily a coding activity, and "object-oriented design" did not exist until about 1980. The programming language people, on the other hand, often lay claim to all things object-oriented, including object-oriented design. Even though a well-defined, quantifiable, transferable, and repeatable process for object-oriented design did not exist until the early 1980s, in their minds OOD has existed at least since there were object-oriented programming languages - a process many people date from 1966 when Similar was first introduced.

As you might guess, there are significant cultural differences between these two groups of object-oriented people. For example, some of those that emphasize rigor and formality view the programming language people as chaotic, overly error prone, wasteful, and largely unpredictable. On the other hand, some of the programming language people consider the "formality" and "rigor" to be mere window dressing - at best adding nothing to the quality of the final product, and at worst increasing the cost of development while simultaneously delaying the delivery and lowering the quality of the resulting software product.

Even if one takes into account the widely different perspectives described above, there are still significant variations within each of these perspectives. Consider inheritance, i.e., the process whereby an object acquires characteristics from another object. A few object-oriented programming languages allow an object to inherit directly from only one other object (single inheritance). Other languages allow an object to inherit characteristics from more than one object (multiple inheritance). Someone who defines OOD in programming language terms may choose to Include or exclude Multiple inheritance from the design process based on whether or not their particular language supports the concept.

Other issues that arise in the programming language camp include the mixing of data and objects, the ability to have program elements that are not encapsulated within any object, and the use of' exceptions, parameterized classes, metaclasses, and concurrency.

Within the "formality and rigor" group there is also a significant amount of diversity. Some try to portray object-oriented methods as slightly recast structured approaches (old wine in new bottles). Others advocate a more data-driven style, e.g., the extensive use of entity-relationship diagrams and other data modeling techniques. Still others seem to have successfully blended object-oriented thinking and rigorous software engineering. In effect, they have integrated the two without losing the benefits of either.

Almost everyone that advocates a formal approach views object-oriented design as only one part of the software development life-cycle. It may be preceded by such activities as object-oriented analysis and feasibility studies, and followed by object-oriented programming (coding). Those accomplishing object oriented design will also be expected to interact with testing, quality assurance, and management personnel. Only if the software problem is small, and of relatively low risk, will object-oriented design be the first life-cycle activity, and even then it will be followed by object-oriented programming.

The word "formal" is sometimes reserved for mathematical (or logically rigorous) approaches to software development. Examples of such approaches include Vienna Development Methodology (VDM), OBJ and

its derivatives, Z, and C.A.R. Hoare's communicating sequential processes. In this unit, we will use the word "formal" more in the sense of "a well-defined, step-by-step, repeatable process with accompanying guidelines, and defined deliverables.")

3.2.1 Programming Language (Non-Formal) Views of OOD

We will use the term "non-formal" to describe approaches to OOD that are not well-defined, step-by-step, or repeatable, such as those that emphasize the design of individual objects, specialization (inheritance) hierarchies, and libraries of objects. A survey of such approaches indicates that there may indeed be some repeatable rigor (and some sage advice) given for these approaches, but they are severely lacking when it comes to defining the software architecture of large/critical systems.

Non-formal OOD approaches usually exhibit many of the following characteristics:

- There is an overriding emphasis on identifying the objects that will make up the application - almost to the exclusion of understanding the overall application. For example, one non-formal approach defines the OOD approach as "identify and create the classes, create instances from the classes, and then have the instances send messages to each other."
- Because of the above, non-formal approaches are often bottom-up in nature. Specifically, one identifies, defines, and implements pieces of the solution, and then merges these pieces into a final or partial solution. (Note that a bottom-up approach need not be chaotic, and may be entirely appropriate for small and/or non-critical problems.)
- Non-formal approaches frequently address issues related to the internal design of individual objects and almost never discuss strategies for the design of the software architecture for the overall application.
- Often there is a blurring of the distinction between the design of an individual object and the design of the application at hand. Specifically, it is not unusual in such approaches to see objects containing application-specific information. (This, unfortunately, reduces the reusability of such objects and decreases the overall reliability of the application.)

3.2.2 Life-Cycle Views of OOD

We now Shift our attention to those who view object-oriented design as one process among several in the development of software products. This view stipulates that, with the possible exception of very simple, non-critical pieces of software, several processes are involved in the creation of software products. These processes have commonly been referred to as "methodologies." (There are those who point out that the "-ology" suffix on methodology should mean "the study of methods," but we will use the term methodology as it is usually understood.)

There are many views as to how to partition the development part of the software product life-cycle. These views can be very simple (e.g., design, followed by coding, followed by testing) or fairly involved (e.g., including feasibility studies, requirements analysis, high-level external design, et cetera).
Virtually all life-cycle views of OOD assume the possibility of some form of analysis (establishing an understanding of the problem to be solved, sometimes coupled with a high-level external description of the solution). Only if the problem is very simple, will the "analysis phase" become optional. Life-cycle views very often consider "coding" to be separate from "design." For example, it is not uncommon to hear statements such as, "no code will be produced until the design is complete."

Software engineers have known for some time that the divisions between various life-cycle phases (e.g., between analysis and design, and between design and coding) are not sharp. Older approaches tended to emphasize the divisions by using different techniques, deliverables, and viewpoints. For example:

- Structured analysis emphasized understanding the way the client conducted business, data flow diagrams, and "the flow of data."
- Structured design, on the other hand, stressed developing an acceptable software system architecture, structure charts, and "the flow of control."

With both increased experience in software development techniques, and an emphasis on an object –oriented view point, the distinctions between various life-cycle phase have become more blurred. Many people have observed that structured analysis, structured design, and structured programming had little in common other than a sense of formality and the adjective "structured." Object-oriented techniques (e.g., object-oriented analysis, object-oriented design, and object-oriented programming), however, tend to be much more consistent with each other.

E.W. Dijkstra introduced the term, and basic concepts behind, "structured programming" in 1969. Although structured programming focused primarily on coding activities, it accelerated a movement that lead to the formalization of other life-cycle phases, e.g., structured design and structured analysis. Object-oriented programming has had a similar effect on life-cycle phases.

One very important difference between the so-called "structured revolution" and the so-called "object oriented revolution" is the much

higher degree of consistency among object-oriented life-cycle phases. For example, the concept of inheritance (specialization) is much the same in object-oriented requirements analysis, in object-oriented design, and in object-oriented programming.

3.3 OOD Approaches

3.3.1 Non-Rigorous OOD Approaches

Dave Bulman ([Bulman, 1989]) and others have observed that the mere identification and creation of objects is not a substitute for "design." It is important to realize that, by "design," Bulman means the establishment of a system architecture. This includes not only the identification of system components (objects), but also the definitions of their interactions and interrelationships as well.

Russell J. Abbott ([Abbott, 1980] and [Abbott, 1983]) described an informal method for specifying the design of a software system. It involved writing a paragraph that described a solution to the problem at hand, and then identifying the nouns and noun phrases as candidate objects. The verbs in the paragraph could then be analyzed to suggest methods (operations) encapsulated within the objects.

Grady Booch adopted the work of Abbott as a mechanism for bringing out the software engineering features of Ada (e.g., [Booch, 1981], [Booch, 1982], [Booch, 1983a], and [Booch, 1983b]). Initially making only a few changes in Abbott's approach, Booch referred to his technique as "object-oriented design." To be sure, Booch was also influenced by Smalltalk, object-oriented computer hardware, and semantic data modeling. One could say that Booch was probably the first person to significantly popularize the term "object-oriented design." (It was not until the mid to late 1980s that people who focused primarily on object-oriented programming languages began using the term OOD with any frequency.)

3.3.2 Moderately Formal OOD Approaches

People who define approaches, guidelines, and techniques for various software engineering activities are commonly called "methodologists." People such as Grady Booch, Larry Constantine, and James Rumbaugh are examples of people who are often referred to as methodologists.

As both the methodologists and the users of their methodologies become more experienced, they cause mutations (clarifications, modifications, and extensions) to the methodologies. In fact, it can be

interesting to follow the evolution of a particular methodology over time gain experience. Thinking on object oriented approaches. Realizing that object-oriented thinking is not limited to design and coding, Booch began to refer to his approach as "object-oriented development."
Some OOD approaches are strongly influenced by particular programming languages. Although the proponents of "responsibility-driven design" do not think of the approach as specific to a particular programming language, its Smalltalk roots are fairly obvious.

As object-oriented technology increases in popularity, people who formerly advocated structured techniques have begun to modify their approaches to encompass object-oriented thinking. The degree of modification varies from author to author.

One technique for creating a "new" methodology is to take one or more important principles from older approaches and then to recast new ideas (e.g., object-orientation) in terms of these principles. The Hierarchical Object-Oriented Design (HOOD) stresses the importance of a top-down approach to software engineering, and places object-orientation within that framework. The General Object-Oriented Development (GOOD) approach advocated by Ed Seidewitz and Mike Stark stressed the importance of understanding a problem in more traditional terms (e.g., data modeling) before moving to an object oriented perspective.

There are other views on OOD that have evolved from fairly unusual perspectives. [Jochem et al., 1989] describes an approach that was influenced by computer integrated manufacturing (CIM). James Rumbaugh ([Blaha et al., 1988] and [Rumbaugh et al., 1991]) advocates an approach that is more closely based on data modeling than on object-oriented thinking. Peter Coad ([Coad and Yourdon, 1991]) describes a "multi-component, multi-layered" approach that is fairly unique.

3.3.3 Mixed Paradigms

There are methodologists that suggest mixing object-oriented approaches with other approaches, and giving each approach equal weighting. [Bewtra et al., 1990] suggests combining object-oriented technology with functional programming ([Backus, 1978] and [Backus, 1982]). [Pendley, 1989] describes a combination of object-oriented thinking and information engineering ([Finkelstein, 1989], [Martin, 1989], [Martin, 1990a], and [Martin, 1990b]). Stream and formal object-oriented specification techniques are advocated in [Toetenel et al., 1990].

3.3.4 Modifying Other Approaches to Encompass Object-Oriented Thinking

When moving from an older way of doing things to a newer way, it is seldom advisable to "throw out" everything connected with the old way. One often used strategy is to enlarge the older way so that it can encompass some or all of the aspects of the newer. Some authors suggest mechanisms for keeping much of traditional structured/functional-decomposition thinking while addressing object-oriented concerns.

3.3.5 Different Paradigms in the Same Life-Cycle

Experience has shown that simply attempting to integrate object-oriented thinking into the more traditional methodologies (e.g., structured) is a mistake. The major problem is that of localization, i.e., the placing of related items in close physical proximity to each other. Functional approaches, for example, tend to localize information around functions, whereas object-oriented approaches tend to localize information around objects. A functional decomposition "front end" to an object-oriented process, in effect, breaks up objects and scatters their parts. Later, these parts must be retrieved and delocalized around objects.

There have been quite a number of attempts to reconcile the output of a non-object-oriented process with the input requirements of an OOD process, but none of these scenarios are as clean and easy as using an object-oriented approach from the very beginning of the software life-cycle.

3.4 Analysis of OOD Approaches

Since object-oriented programming has been with us for more than a quarter of a century, and OOD proper has been around for over a decade, it is not unusual that a number of attempts have been made to analyze the OOD process. While some of these analysis reveal potential problems with particular OOD approaches, none have advocated avoiding an object-oriented approach.

Comparisons
Comparisons of methodologies have been around since the 1970s. The first significant comparison of OOD with Structured Analysis/Structured Design and Jackson System Development was done under the auspices of General Electric ([Boelim-Davis and Ross, 1984]). This study gave the same problem to three different groups of people, and had them all implement solutions using the same programming language.

When compared with the other solutions, the researchers found that the OOD solutions:

- were simpler (using control-flow complexity and numbers of operators and operands as metrics),
- were smaller (using lines of code as a metric),
- took less time to develop, and
- were better suited to real-time problems.

Some comparisons have been very informal (e.g., [Boyd, 1987] and [Jamea, 1984]), while others have been flawed because the authors did not fully understand what OOD was.

OOD Techniques

A number of authors, while not describing complete OOD methodologies, have described techniques that can be used in the OOD process. [Beck and Cunningham, 1989], for example, describes Class responsibility-Collaboration (CRC) cards. The idea is to create one CRC card for every class involved in the problem or solution. The responsibilities (method interfaces) of the object are documented on one area of the card and the collaborations (other objects with which the object must interact) are placed on another area.

[Byrne and Kwiatkowski, 1986] describe a graphical means of representing objects in an OOD process. In the same vein, [Coleman et al., 1992] describes a variation on state charts ([Harel, 1987] and [Harel et al., 1987]), i.e., "object charts." (Loomis et al., 1987] defines a graphical technique that is used in tile OOD approach advocated by James Rumbaugh.

Experiences With OOD

One of the sign of a maturing technology is the emergence of “war stories,” i.e., accounts of the experiences of those who have used the technology. [Chedgey et al., 1987] describes an attempt to use a formal methodology (Vienna Development Method, e.g., [Jones, 1986]) with OOD. [Meyer et al., 1989] talks about the experience of using an approach to OOD that mixes functional decomposition with more traditional object-oriented techniques. [Davis and Irving, 1989] presents a discussion of one of the most common uses of OOD, i.e., for real-time systems. [Vlissides and Linton, 1988] describes the use of OOD for the creation of a graphics application.

Metrics

Even before Tom Glib wrote his landmark book on software metrics ([Glib, 1977]), people had been interested in measuring software. While there are now numerous metrics for measuring non-object oriented

software (e.g., [Arthur, 1985], [Card and Glass, 1990], [Conte et], [Dreger, 1989], [Ejiogu,

1991], [Grady and Caswell. 1987], and [Jones, 19911). there are relatively few discussions on metrics for object-oriented software.
Karl Livebearer and his colleagues have written a number of articles on assessing the quality of the design of an individual object (e.g., [Livebearer and Riel, 1989]). However, until very recently, there has not been much published. [Chidambaram and Kemmerer, 1991] is probably the most comprehensive article to date on assessing the quality of an object-oriented design.

Computer Aided Software Engineering For OOD
Computer aided software engineering (CASE), once considered a luxury, is becoming increasingly necessary in today's software engineering arena. With the rising interest in object-oriented software engineering, it is only natural to ask, "Where are the CASE tools for object-oriented technology?"

One of the major obstacles to OOD CASE tools is the wide variety of approaches. Some OOD methodologists, or their organizations, have put out their own CASE tools, e.g., Rationale's ROSE(tm) and Object International's OOATool(tm). Some CASE vendors have chosen to automate the approaches from several different methodologists, e.g., Mark V Systems, Ltd.'s Object Maker(tm) and Photoset Ine.'s Paradigm Plus(tm). However, it will be some time before the object-oriented technology market becomes as focused as the so-called structured technology marketplace.

4.0 CONCLUSION

Object-oriented technology has many different dimensions, viewpoints, and implementation strategies. Those considering using OOD on a project have many different options from which to choose. However, the "right choice" will require careful research.

5.0 TUTOR-MARKED ASSIGNMENT

1. Describe briefly the origin of Object-Oriented Design
2. Discuss the two views of Object-Oriented Design

6.0 REFERENCES/FURTHER READING

Object-Oriented Design By Edward V. Berard

UNIT 4 OBJECT-ORIENTED ANALYSIS AND DESIGN

CONTENTS

1.0 INTRODUCTION

Most new client/server application development tools emphasize object-oriented (00) features. This implies that an 00 analysis and design (OOAD) methodology should be an effective guide to applying these tools to business problems. But with the numerous methodologies available for OOAD, how do you choose the correct one? How do you get started, and how do you ascertain whether your approach is as efficient as it should be? And how do you avoid the pitfalls? OOAD can provide wonderful benefits, but believing that a new methodology will solve all your problems is like believing in Utopia.

In this unit we will discuss a number of Object-oriented Analysis and Design methodologies.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the origin of Object-oriented design
- differentiate between the two cultures in the "object-oriented community"

3.0 MAIN CONTENT

3.1 Object-Oriented Analysis and Design

A survey of available literature shows that the applications competing for "object honors" are written mostly in C++ or Smalltalk, and have a heavy manufacturing, engineering, aerospace, or scientific focus. That the major OOAD methodologies are best for such problems, however, does not guarantee that they are also best for typical business client/server applications. You need to determine which methodology is best suited for your particular application, and what to do if no methodology matches your requirements precisely. (Using OOAD often requires adaptations to methodologies.)

3.2 The Role of GOAD in the Software Life Cycle

To understand what's right and wrong with OOAD, you need to know where 00 methodologies fit into the software life cycle. These methodologies do not replace traditional approaches (such as data flow, process flow, and state transition diagrams); they are important new additions to the toolkit.

According to Donald Fire Smith in his book Dictionary of Object Technology (SIGS Books, 1995), analysis is "the development activity consisting of the discovery, modeling, specification and evaluation of requirements," while 00 analysis is "the discovery, analysis and specification of requirements in terms of objects with identity that encapsulate properties and operations, message passing, classes, inheritance, polymorphism and dynamic binding." Fire smith also states that 00 design is "the design of an application in terms of objects, classes, clusters, frameworks and their interactions."

In comparing the definition of traditional analysis with that of OOAD, the only aspect that is really new is thinking of the world or the problem in terms of objects and object classes. A class is any uniquely identified abstraction (that is, model) of a set of logically related instances that share the same or similar characteristics. An object is any abstraction that models a single thing, and the term "object" is synonymous with instance. Classes have attributes and methods. For an object class named Customer, attributes might be Name and Address, and methods might be Add, Update, Delete, and Validate. The class definition defines the Customer class attributes and methods, and a real customer such as "XYZ Corp." is an instance of the class. If you have different kinds of customers, such as residential customers and commercial customers, you can create two new classes of customers that are descendants of the Customer class. These descendants use inheritance to gain access to all

of the Customer class attributes and methods, but can override any of the ancestor attributes and methods, as well as contain any required new attributes and methods.

There are three types of relationships between classes: inheritance, aggregation, and association. Inheritance (also referred to as generalization/specialization) is usually identified by the phrase "is a kind of." For example, Student and Faculty are both a kind of Person and are therefore inherited from the Person class. Aggregation is identified by the phrase "is a part of," as with a product that contains parts. If neither of the first two relationships applies; but the objects are clearly related (for example, an employee is associated with a company), then the relationship is association.

An abstract class is a class that has no instances, and is used only for inheritance. A concrete class is a class that can be instantiated, that is, that can have direct instances.

All of the major OOAD methodologies have a similar basic view of objects, classes, inheritance, and relationships. The drawing notation is slightly different in each; the real differences in the methodologies are more subtle.

Table 1 (below) summarizes the major GOAD methodologies. When you're choosing a methodology, it is important to consider not only the methodology's features, but also the cost of using it, the types of problems to which it is best suited, its limitations, and the training available. When used in typical initial attempts to develop client/server applications using OOAD methodologies, all of the methodologies suffer from the same basic flaws:

- an overemphasis on the 00 approach in general, even though another approach might be better for some parts of the problem
- an overemphasis on the problem domain object model during the analysis phase
- analysis diagrams and output formats that end users may find difficult to understand
- difficulty in the methodology's ability to describe complex analysis problems
- a lack of emphasis on the underlying system architecture
- an inability to understand the limitations of either 4GL OO languages or of beginning OO developers

Table 1. Major OOAD Methodologies

Analysis Methodology	Proprietary	Type	Scope	Strengths	Primary Cited Applications / Markets
Booch	No	Ternary	Complex, Rich. Pragmatic	Design	All
Coad and Yourdon	No	Unary	Simple, Limited. Pragmatic	Analysis	Client/Server
Fusion	No	Ternary	Complex, Rich. Pragmatic	Full Life Cycle	All
Jacobson Objectory	Yes	Ternary	Complex, Rich	Full Life Cycle	All
LBMS SEoo	Yes	Ternary	Middle of the Road. Pragmatic	Full Life Cycle	Client/Server
Rumbaugh	No	Ternary	Complex, Rich. Somewhat Pragmatic	Analysis & Design	All, but heavily Embedded. Real-Time
Shlaer and Mellor	No	Ternary	Complex, Rich	Design	Embedded, Real-Time

Every object methodology tells you to start with the object model, not the data model; there are at least four problems with this approach:

- The data model often exists before the object model.
- The analyst may rightly be more comfortable building the data model before the object model.
- A good object model should be able to map to any data model. For me, it is usually a requirement in complex systems that an object's attributes can map to one or more tables in one or more databases.
- A good abstract object model of the problem domain may not be easy to implement in the chosen language or development tool.

3.3 OOAD Methodologies

OOAD methodologies fall into two basic types. The ternary (or three-pronged) type is the natural evolution of existing structured methods and

has three separate notations for data, dynamics, and process. The unary type asserts that because objects combine processes (methods) and data, only one notation is needed. The unary type is considered to be more object-like and easier to learn from scratch, but has the disadvantage of producing output from analysis that may be impossible to review with users.

Dynamic modeling is concerned with events and states, and generally uses state transition diagrams. Process modeling or functional modeling is concerned with processes that transform data values, and traditionally uses techniques such as data flow diagrams.

In the following sections, 1 describe the methodologies of Booch, Coad and Yourdon, Fusion, Jacobson, LBMS, Rumbaugh, and Shlaer and Mellor. There are several other methodologies that I don't discuss, and if you are interested in learning more about them, I strongly recommend Ian Graham's book, Object-Oriented Methods (Addison-Wesley, 1994), which does an excellent job of both describing and comparing available methodologies.

3.3.1 Booch

Grady Brooch’s approach to OOAD is one of the most popular, and is supported by a variety of reasonably priced tools ranging from Visio to Rational Rose. Booch is the chief scientist at Rational Software, which produces Rational Rose. (Now that James Rumbaugh and Ivar Jacobson have joined the company, Rational Software is one of the major forces in the OOAD world.)

Booch's design method and notation consist of four major activities and six notations, as shown schematically in Table 2.

While the Booch methodology covers requirements analysis and domain analysis, its major strength has been in design. However, with Rumbaugh and Jacobson entering the fold, the (relative) weaknesses in analysis are disappearing rapidly. I believe that Booch represents one of the better developed OOAD methodologies, and now that Rational Rose is moving away from its previous tight link with C++ to a more open approach that supports 4GLs such as PowerBuilder. the methodology's popularity should increase rapidly.

Table 2. The Steps in Booch's Methodology

Steps	Notations
Logical structure	Class Diagrams Object Diagrams
Physical structure	Module Diagrams Process Diagrams
Dynamics of Classes	State Transition Diagrams
Dynamics of Instances	Timing Diagrams

For systems with complex rules, state diagrams are fine for those with a small number of states, but are not usable for systems with a large number of states. Once a single-state transition diagram has more than eight to 10 states, it becomes difficult to manage. For more than 20 states, state transition diagrams become excessively unwieldy.

3.3.2 Coad and Yourdon

Coad and Yourdon published the first practical and reasonably complete books on OOAD (Object Oriented Analysis and Object-Oriented Design, Prentice-Hall, 1990 and 1991, respectively). Their methodology focuses on analysis of business problems, and uses a friendlier notation than that of Booch, Shlaer and Mellor, or the others that focus more on design.

In Coad and Yourdon, analysis proceeds in five stages, called SOSAS:

- Subjects: These are similar to the levels or layers in data-flow diagrams and should contain five to nine objects.
- Objects: Object classes must be specified in this stage, but Coad and Yourdon provide few guidelines for how to do this.
- Structures: There are two types: classification structures and composition structures. Classification structures correspond to the inheritance relationship between classes. Composition structures define the other types of relationships between classes. Coad and Yourdon do not deal as well as Rumbaugh, Jacobson, and several other methodologies do with these structures.
- Attributes: These are handled in a fashion very similar to that in relational analysis.

- Services: The identification of what other methodologies call methods or operations.

In design, these five activities are supplanted by and refined into four components: problem domain component: classes that deal with the problem domain; for example, Customer classes and Order classes human interaction component: user-interface classes such as window classes:

- task management component: system-management classes such as error classes and security classes
- data management component: database access method classes and the like

Although Coad and Yourdon’s methodology is perhaps one of the easiest 00 methodologies to learn and get started with, the most common complaint is that it is too simple and not suitable for large projects. However, if you adhere to a premise that you should use those pieces of a methodology that work, and add other parts from other methodologies as required, Coad and Yourdon's methodology is not as limiting as its critics claim.

3.3.3 Fusion

In 1990, Derek Coleman of Hewlett-Packard led a team in the U.K. to develop a set of requirements for OOAD, and conducted a major survey of methods in use at HP and elsewhere. The chief requirement was a simple methodology with an effective notation.

The result was Fusion, Which Coleman and others developed by borrowing and adapting ideas from other methodologies. They incorporated some major ideas from Booch, Jacobson, Rumbaugh, and others, and explicitly rejected many other ideas from these methodologies.

Coleman did not use some of the major components of Rumbaugh and Shlaer and Mellor in Fusion, because the components were not found to be useful in practice. Some writers have called this encouraging and remarkable, and consider it indirect proof that excessive emphasis on state models comes from Rumbaugh and Shlaer and Mellor's telecommunications and real time system backgrounds.

Fusion's pragmatic approach seems to hold considerable potential for client/server applications, but this methodology is not being marketed as aggressively as most of the other methodologies.

3.3.4 Jacobson: Objectors and DOSE

Although Jacobson's full OOAD methodology, Objectory, is proprietary (to use it you must buy consulting services and a CASE tool, OrySE, from Rational Software), it is probably the most serious attempt by an OOAD tool vendor to support the entire software development life cycle. Jacobson is considered to be one of the most experienced 00 experts for applying 00 to business problems such as client/server applications.

Jacobson's Object-Oriented Software Engineering (OOSE) is a simplified applications. According to Jacobson: "You will need the complete ... description which, excluding large examples, amounts to more than 1200 pages" (Object-Oriented Systems Engineering, Addison-Wesley, 1992).

Object modeling and many other 00 concepts in Objectory and OOSE are similar to 00 concepts in other methodologies. The major distinguishing feature in Jacobson is the use case. A use-case definition consists of a diagram and a description of a single interaction between an actor and a system; the actor may be an end user or some other object in the system. For example, the use-case description of an order entry application would contain a detailed description of how the actor (the user) interacts with the system during each step of the order entry, and would include descriptions of all the exception handling that might occur.

3.3.5 LBMS SEOO

Systems Engineering 00 (SE00) is a proprietary methodology and toolkit from the U.K.-based company LBMS, which has its U.S. headquarters in Houston. SE00 is tightly integrated with Windows 4GLs such as PowerBuilder, and is perceived to be a very pragmatic and useful tool, but this perception may be due in part to a stronger marketing effort than is often made for nonproprietary methodologies.

Because SE00 is proprietary, there is not as much detailed information available about it as there is about other methodologies, and it is somewhere between difficult and impossible to try it out just to compare it with the others.
The four major components of the SE00 methodology are:

- work-breakdown structures and technique
- an object modeling methodology
- GUI design techniques

- relational database linkages to provide ER modeling and 4GL-specific features with non-00 approaches and then adapting to 00. /A very positive aspect of this is the heavy focus on data management and data modeling. SE00 is intended to be object oriented while retaining the advantages of traditional data modeling. This makes the methodology well-suited for client/server database applications. SE00 is unique in treating data, triggers, and referential-integrity rules as a set of shared objects in a database. It treats a data model as a view of the shared objects, which also include constraints, rules, and dynamics (state transitions and so on). SE00 draws a clear line between shared objects and other objects, and regards the shared objects as important interfaces between subsystems. This technique allows a distinction, for example, between customer behavior shared by all applications and customer object behavior unique to a single application. It is a technique with which a purist would quibble, but which is eminently practical.

3.3.6 Rumbaugh OMT

James Rum Baugh's methodology, as described in his book Object-Oriented Modeling and Design (Prentice-Hall, 1991), offers one of the most complete descriptions yet written of an 00 analysis methodology. Although it is somewhat lacking in 00 design and construction, it contains a large number of ideas and approaches that are of significant use to analysts and designers.

Analysis consists of building three separate models:

- the Object Model (OM): definition of classes, together with attributes and methods; the notation is similar to that of ER modeling with methods (operations) added
- the Dynamic Model (DM): state transition diagrams (STDs) for each class, as well as global event-flow diagrams
- the Functional Model (FM): diagrams very similar to data flow diagrams

3.3.7 Shlaer and Mellor OO Analysis

When Shlaer and Mellor 00 analysis first came out in 1988, it represented one of the earliest examples of 00 methodology and it has evolved very positively since then.

Originally an object-based extension of data modeling, the Shlaer and Mellor methodology starts with an information model describing objects, attributes, and relationships. (Note that this is more like a data model than an object model.) Next, a state model documents the states

of objects and the transitions between them. Finally, a data-flow diagram shows the process model.

4.0 CONCLUSION

No one feature will make all software trivial to write, and no one architecture will be ideal for all problems. Creating good software will continue to be hard work. Each of these methodologies are very useful for particular situations.

5.0 SUMMARY

In this unit you have learned about the role of object-oriented analysis and design in the Software Life Cycle and you have been introduced to some of the major OOAD methodologies.

6.0 TUTOR-MARKED ASSIGNMENT

Outline FOUR OOAD methodologies and briefly describe them.

7.0 REFERENCES/FURTHER READING

Michael Gora, Object-Oriented Analysis and Design

UNIT 5 OBJECT-ORIENTED SOFTWARE DESIGN

CONTENTS

1.0 INTRODUCTION

For any real-world problem, you have to design the software - identify the objects and their interrelationships - before you can write any code to implement the objects in an object-oriented language such as C++. In fact, this early part of the software development process - the analysis and design phases - is much harder than the actual coding because there are no well-defined, step-by-step methods for accomplishing the job. The best you can do is to learn about the prevailing practices in object-oriented analysis and design and adapt them to your problem.

This unit provides a summary description of some of the current ideas in the field of object-oriented design. However, the unit does not attempt complete coverage of object-oriented design.

2.0 OBJECTIVES

After completing this unit, you should be able to;

- describe the sequence of activities that constitute software development
- identify methods and tools for accomplishing the analysis and design phases of the designing software
- enumerate the problems with top-down approach to software design
- describe the use of object-oriented techniques in software development process

3.0 MAIN CONTENT

3.1 Software Engineering Trends

Looks on software engineering show the traditional lifecycle of software development in the form of a waterfall (see Figure 5.1), in which the development process follows a rigid sequence from analysis to design and to implementation and testing. Based on that waterfall process, here is an oversimplified view of the sequence of activities that constitute software development:

1. You begin development with the analysis phase by analyzing what the software must do and arriving at a complete, detailed description of the software's behavior in response to the possible set of inputs. You work with potential users of the software to find a definitive answer to the question: What does the software do? The result of this step is a set of requirements for the software.

2. Next comes the design phase, during which you decide how to do what the user wants. Here your goal is to map the user's real-world description of the software into algorithms and data that can be implemented in a programming language. Typically, you might follow a top-down approach and repeatedly decompose the software's functions into a sequence of progressively simpler functions that are eventually implemented in the implementation phase.

3. In the implementation phase you define the data structures and write the code to implement the functions that were identified in the design. Finally, you have to test the software to verify that it conforms to the original specification as much as possible.

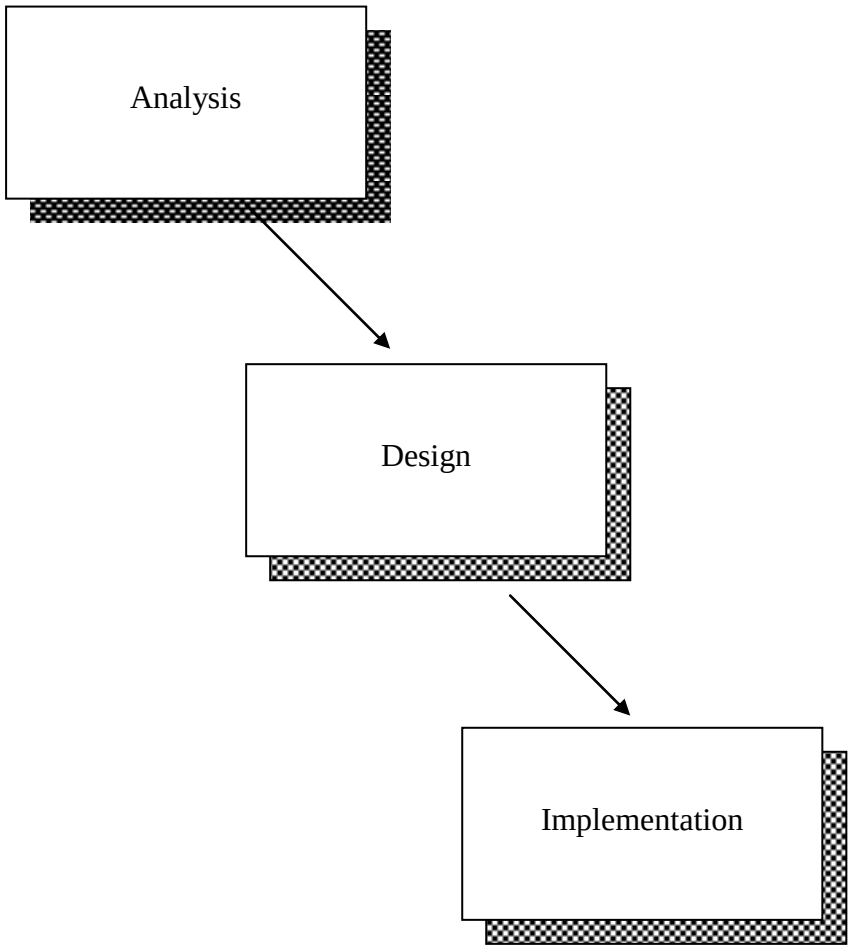


Figure 5.1 Traditional Life Cycle of Software

3.1.1 Prevailing Methods

Although there is no single, clear-cut, step-by-step approach to designing software, there are well-known methods and tools for accomplishing the analysis and design phases of the process.

Among the analysis methods, the most popular is structured analysis, attributed to Tom DeMarco, who built on prior work by Ed Yourdon and Larry Constantine. Structured analysis is concerned with the way data flows through the system. It generates a data flow diagram (DFD) and two textual descriptions: a data dictionary and a minispecification. The DFD is a diagramming notation that depicts the flow of data through the system and identifies the processes that manipulate the data. The data dictionary describes the data shown in the DFD, whereas the minispecification describes, in plain English, how the data is processed

by each process. As an example, consider the problem of querying a database and printing a sorted list of the items retrieved by the database. Figure 5.2 shows a grossly simplified data flow diagram for this task. The diagram shows the major processes (functions), with arrows indicating the data being passed between functions.

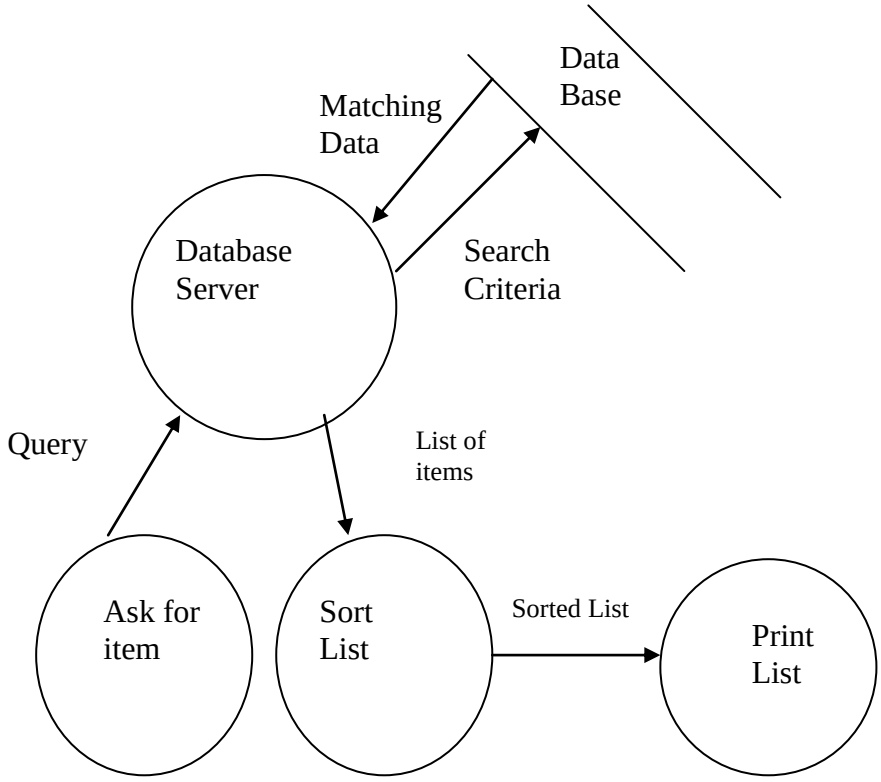


Figure 5.2 Data Flow Diagram (DFD) for querying a database

Another type of diagram for representing a software system is the structure chart introduced by Larry Constantine in the 1970s as a replacement for flowcharts of earlier years. The structure charts are quite similar to the flowcharts, and they provide a notational means to represent the behaviour of the system being implemented. As shown in Figure 5.3, a structure chart starts with a single top-level module represented by a rectangle. That module represents the overall function of the system. From that topmost module, arrows fan out to subordinate modules that the topmost module invokes. The subordinate modules, in turn, invoke other modules. Thus, the structure looks like an organization chart, reflecting the top-down nature of the design. Each arrow emanating from one module to another represents a function call as well as a data transfer. In an actual structure chart, a label next to each arrow identifies the data being transferred. There are other symbols

as well as that indicate program's control flow, such as if statements and loops. Many commercially available computer-aided software engineering (CASE) tools support structure charts with symbols similar to those originally suggested by Larry Constantine.

Solve Problem 1
Part 1 Part 2 Part 3 'Task A Task 6
Library 1

Which problem?

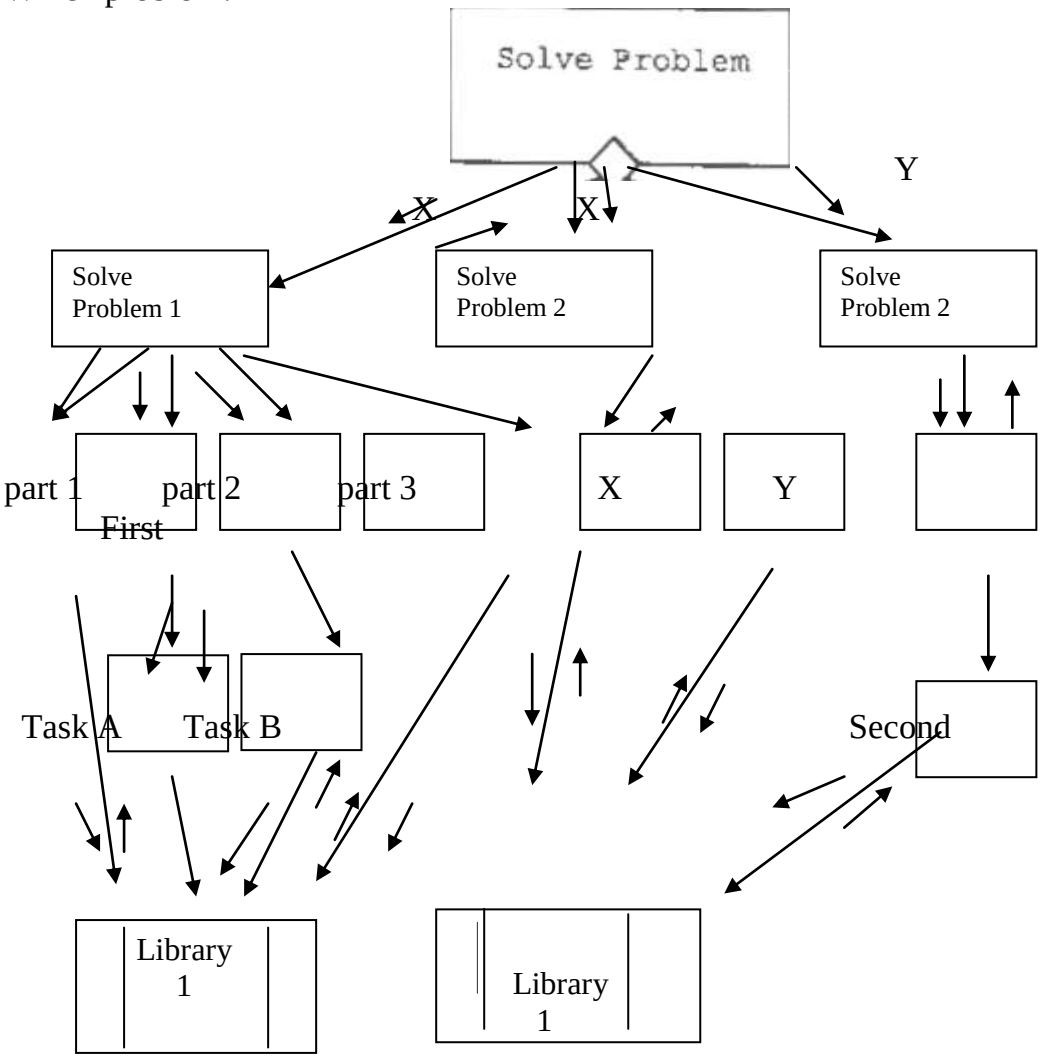


Figure 5.3 A typical structure chart

The design phase of the traditional development cycle is rather loosely defined. The goal of design is to refine the data flow diagrams and map the data into data structures using facilities of the programming language (for example, struck in C) that you will use to implement the software. Procedures are then defined to implement the modules that manipulate the data. The distinction between the analysis and design

phases are often blurred and, usually, there are several iterations before you arrive at a design for the software.

3.1.2 Problems with the Top-Down Approach

There are several problems with the top-down approach so prevalent in structured techniques. As Bertrand Meyer points out, top-down design :

- does not allow for evolutionary changes in software.
- characterizes the system as having a single top-level function, which is not always true (in Meyer's words: "Real systems have no top").
- gives functions more importance than data, thus ignoring important characteristics of the data.
- hampers reusability, because sub modules are usually written to satisfy the specific needs of a higher-level module.

3.2 Object-Oriented Approach

In any realistic software project, post-implementation changes are all but evolutionary. Because we learn as we go along, our usual approach to a new programming task is to go through an iterative process of analyzing the problem, implementing it, and then refining the design. In other words, we develop prototypes or working models of the software. Grady Booch calls this the strategy of "analyze a little, design a little." He qualifies this by stating that it does not mean that you should design by trial and error. Instead, Booch advocates a design process that proceeds with a series of prototypes, each modeling an important aspect of the system and each selected with an eye toward arriving at the complete functionality as the collection of prototypes grows.

The emerging object-oriented design (OOD) techniques reflect the evolutionary aspect of software development. The steps of analysis, design, and implementation are still necessary, but the separation between them is blurred. Also, the approach in each phase is more closely tied to the objects in the real world problem being solved. The remainder of this unit briefly discusses several ways of using object oriented techniques in the software development process.

3.2.1 Finding Objects Using Structured Analysis Tools

At the implementation level, object-orientation means encapsulating data structures with related functions and using the notion of "message-passing" (which may very well be implemented by function calls) to accomplish the tasks of a program. The question in object-oriented design is how to find the objects. For those already familiar with

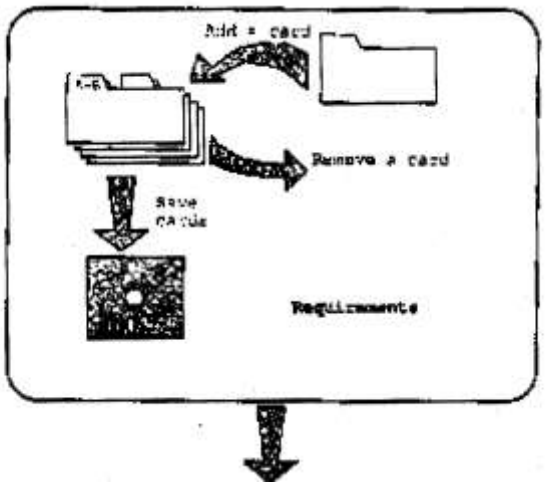
structured analysis, the answer may be in using the results of structured analysis to find the objects to be implemented using OOP techniques. This approach can be exploited by commercial software developers who are trying to introduce object-oriented technology but have already invested in CASE tools that employ top-down analysis and design.

A class is the template that defines the data and functions common to a set of objects. Each object is an instance of its class. A class library is a collection of classes, usually meant for some related tasks such as displaying objects or storing them on disk.

Figure 5.4 illustrates the steps for a simplified example of finding the objects for an index card file. Each card stores a name, address, and phone number. Conventional structured analysis will model the card file as follows:

Identify the requirements of the card filing system. In this case, the system must be capable of creating a new card deck, adding or deleting a card, finding a card, and saving cards in a disk resident database.

Translate the requirements into a top-down structure in which the topmost module enables the user to pick one of several choices: create a new deck, save it, add a card, delete a card, or find a card. Each choice is handled by separate modules. The analysis also identifies the data items and how they are processed. Typically, you will use libraries of functions for specialized tasks such as displaying a card or organizing the deck of cards as a database.



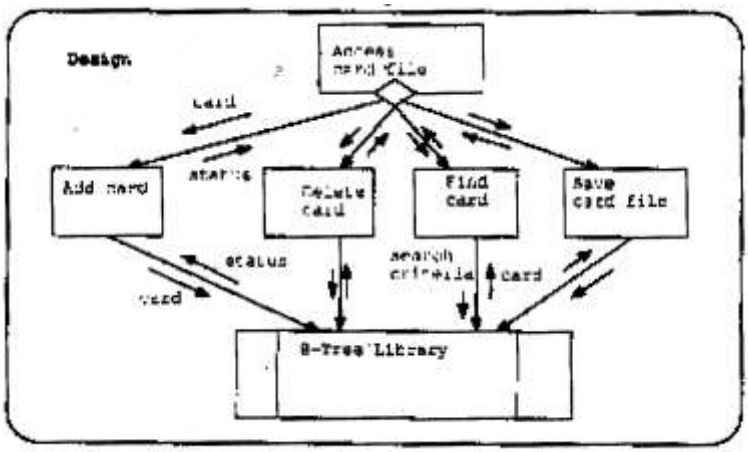


Figure 5.4 Designing a card file

You can use existing CASE tools in performing the analysis to determine the functional breakdown of the system and identify the necessary data items (from the data dictionary, for instance). At this point, instead of using the CASE tool to design the system, you can try to identify the objects from the data and the functions. For the card file, here is a partial description of how you might do this:

- Note that cards are manipulated by most modules identified by structured analysis. Thus, each card should be an object in the system. In C++ terminology, you might decide to define an Index card class, for instance, to encapsulate the data and functions necessary to model an index card.

- Because a card file is a collection of cards, there should be a way to maintain such a collection. You might use a container class (a class designed to hold objects) or simply use an array of Index Card objects for this.

- Each card has several strings to hold information such as the name and address. For this, you can use a String class that enables you to handle each string as an objects. When a new card is created, you can create the necessary string objects.

- You can choose from among three options for obtaining the database that will store the cards. You can design a complete set of classes, implementing a database in an object-oriented manner. You can buy a commercially available library of classes and use it. Lastly, you can directly call functions from the programming interface to a commercial database that does not follow an object-based design. The problem with the last approach is that embedding calls to a database in the Index Card

class, for instance, couples the card class too tightly to a specific database.

As you can see, the process of identifying the objects can be quite complicated, even for a relatively simple example such as the card file. Even so, there are some general guidelines for identifying the classes:

- Look for data and related functions that operate on the data. Group them into a class.

- If a class seems too specific, try to derive it from a more general-purpose class. The idea is to look for similarities among classes and to create a hierarchy in which the common features are in a base class. For example, instead of implementing a circle and a rectangle shape, first define a generic shape class, then derive circle and rectangle classes from that generic shape. That way, a new shape, such as a triangle, can be derived easily from the same base.

- Use a bottom-up approach to design libraries of basic classes such as strings and collections. For example, if you design a database for the card file, it can be a general-purpose database class that can be reused in other projects as well.
- Avoid embedding in a class any code for displaying an object or storing it to the disk. Instead, use a separate class library for these tasks.

Unfortunately, as fuzzy as these guidelines are for identifying objects and their interrelationships, the material in most of the references listed at the end of this chapter is not any more specific. Luckily, this situation is bound to improve, because object-oriented design is the current topic of choice among many researchers and new design methods are gradually beginning to emerge. The following discussions summarize some important ideas that can help you gain insight into designing object-oriented software.

3.2.3 Notation for Objects

Diagrams are an essential part of any design, and object-oriented design is no exception. Unfortunately, there is no standard notation for representing objects and their interactions. Authors of books on object - oriented techniques have used their own notations to denote objects. Recently other suggested notations have appeared in computer journals. Of these, Wasserman, Muller, and Pitcher have based their notation on a combination of structure charts and the notation that Booch uses for Ada

packages - modules in the Ada programming language. Figure 5.5 shows a subset of Wasserman's notation that is adequate for representing objects. The notation developed by Wasserman and colleagues is used in a design technique termed object-oriented structured design (OOSD), which forms the basis of a useful design tool named Software Through Pictures developed and marketed by Interactive Development Environments, Inc.

3.2.4 Hybrid Design Methods

One trouble with using structured analysis as a basis for object-oriented design is that the two approaches use radically different grouping of the functions in the system. As Bailin points out, structured analysis groups functions together if, as a group, they constitute a higher-level function. On the other hand, object-oriented analysis groups functions together on the basis of the data they operate on. Thus, in object-oriented approach, all functions operating on the same class of data fall in the same group.

This, however, does not mean that structured analysis is not useful. In fact, according to Larry Constantine, one of the pioneers of the structured approach, it may be more useful and even practical to use a mix of top-down functional analysis together with object-orientation. Here are three possible scenarios:

- An object-oriented system with top-down functional decomposition applied to each object's methods: You decompose the system into interacting objects, either by identifying the objects from the output of a CASE tool or by using one of the methods discussed later in the chapter. Then, you apply top-down structured analysis techniques to design the object's internal methods (member functions in C++ terminology). In this case, outwardly, the system appears object oriented, but inside each object there may be a small hierarchy of functions designed in a top down manner (see Figure 5.6).

- A top-down hierarchy of functions controlling the system that employs object-oriented modules for its functionality: As you can see from Figure 5.7, in this case you design the system using a top-down approach, but you implement the modules by using a set of interacting objects.

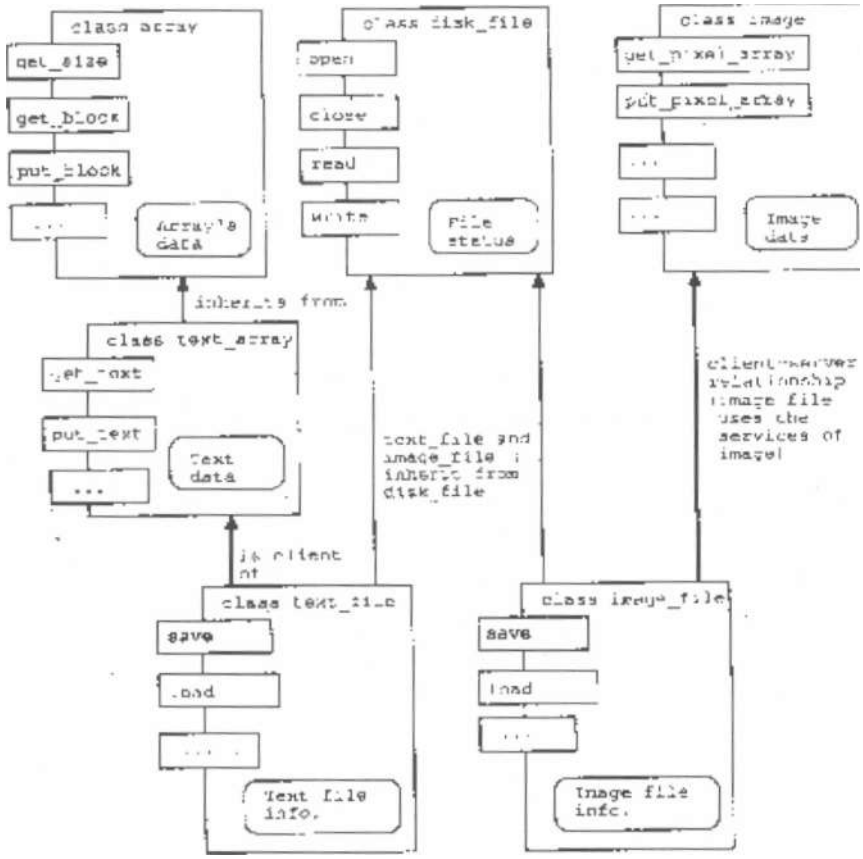


Figure 5.5 Notations for objects and their interactions

- An object-oriented system built on a traditional library of functions: This is a common case when you are building an object-oriented system using the facilities of a conventional library of functions such as Xlib - the C function library for the X Window System. As illustrated in Figure 5.8, the objects call functions from the library to do their work, but the application is built on the objects.

3.2.5 Using Physical Metaphors: The Desktop

One way to design software is to find the right physical metaphor for the various features of the software you are designing. For example, the user interface in Apple Macintosh computers uses the desktop metaphor. You are supposed to view the display as desktop containing folders and files of all information laid out like paper. You can shuffle these "papers" around, keeping in view the one you are currently using. To use a document, you simply open it and the right application gets started. The desktop metaphor is extended to the point that there is even a trashcan where you discard files and folders that you no longer need. As with a real world trashcan, you have to empty this trashcan before the items are actually deleted from the system's disk.

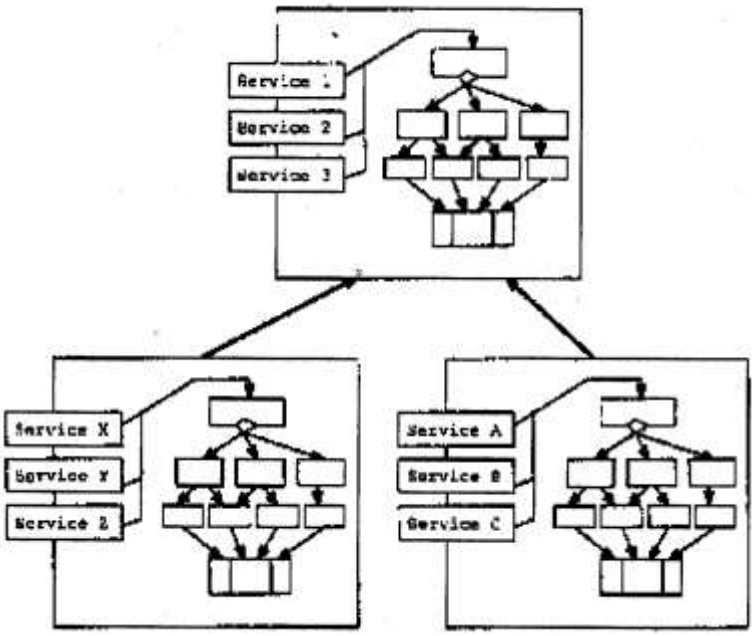


Figure 5.6 Object-oriented system with top-down design internal to objects

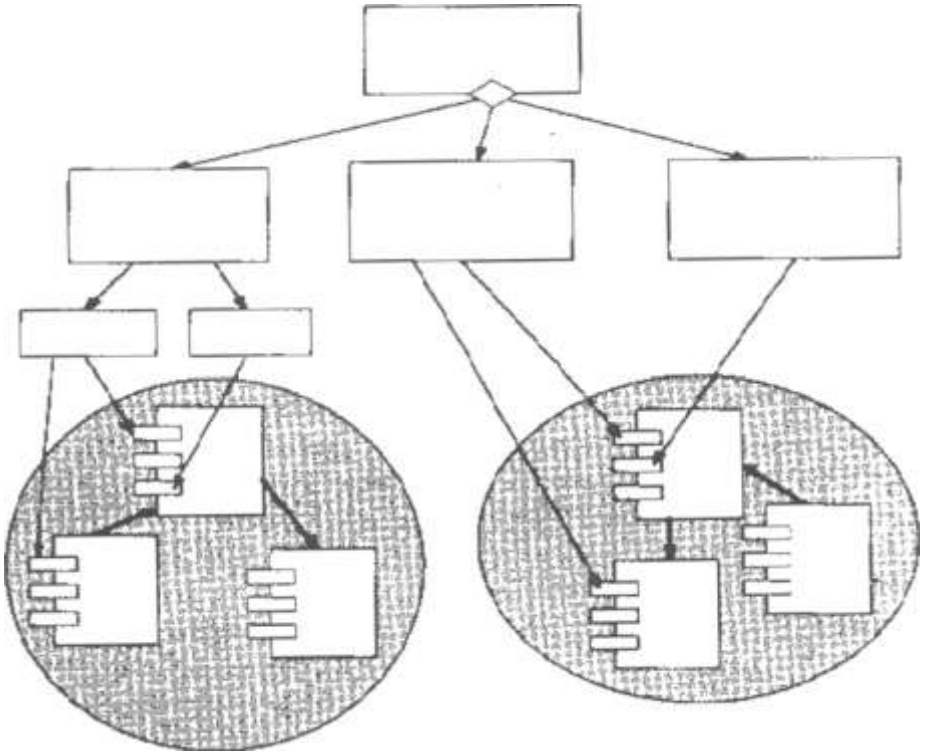


Figure 5.7 Top-down design with functionality from objects

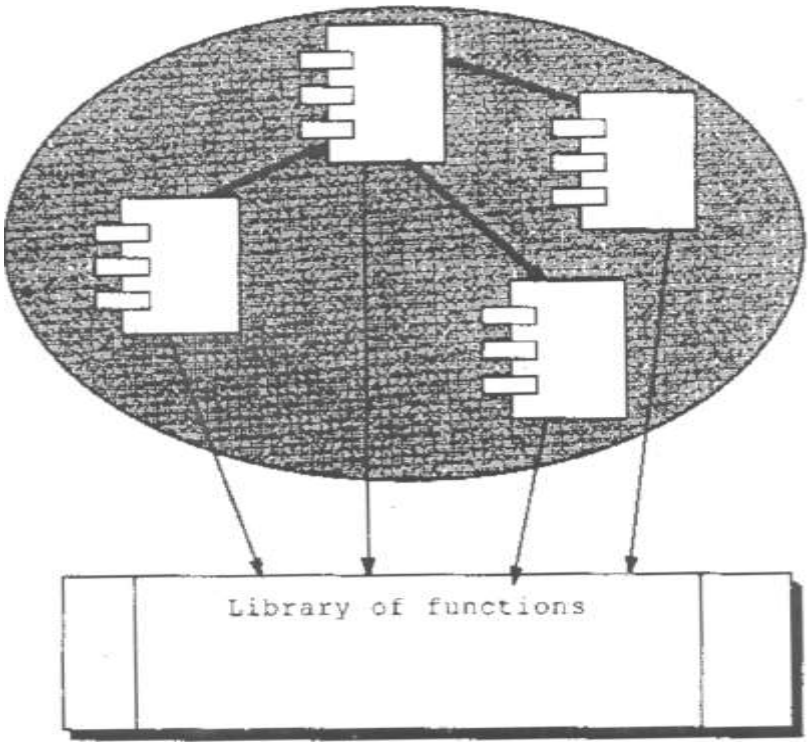


Figure 5.8 Object-oriented system built atop the functional layer

The advantage of using such physical metaphors is that your job as a designer metaphor, you do not necessarily have to use an object-oriented approach to exploit a metaphor, but physical metaphors lend themselves more readily to object-oriented organization. After all, the objects in the software can be the direct counterparts of the objects that are art of the physical metaphor.

The idea of using electronic circuits as a metaphor may seem natural for simulating actual integrated circuits (ICS), but you can use this metaphor to build user interfaces. In fact, the idea of software packaged as ICs was first used by Brad Cox, who also coined the term software-IC. Suppose you are using a windowing system such as the X Window system to implement a user interface. Here is a rough idea of how you might use the electronic circuit metaphor (see Figure 3.9) to implement the user interface:

- Think of each window as an IC with a number of input pins.
- Provide "connector" objects and functions to connect one pin to another. Use a linked list of connectors to handle multiple connections at a pin.
- Allow signals to be sent from output pins to input pins. This means that you need signal objects. Signals arriving at an input pin can be handled by calling a function inside the IC.

- As the user provides input with mouse or keyboard, send signals arriving at air input pin can be handled by calling a function inside the IC.
- As the user provides input with mouse or keyboard, send signals out on appropriates pins to perform the task requested by the user.

Depending on your application, this can turn out to be a useful metaphor. For example, you might exploit such a metaphor in an application with which the user interactively builds a graphical user interface. With such a metaphor, the user can select individual user interface components and connect their input and output pins to build, and interface. You could provide some means for exercising the interface and, when the user is satisfied, allow generation of code that implements the interface.

4.0 CONCLUSION

Object-oriented programming (OOP) refers to the implementation of programs using objects, preferably in an object-oriented programming language such as C++. Object-oriented analysis (OOA) refers to methods of specifying the requirements of the software in terms of real-world objects - their behaviour and their interactions. Object-oriented design (OOD), on the other hand, turns the software requirements into specifications for objects and derives class hierarchies from which the objects can be created. OOD methods usually use a diagramming notation to represent the class hierarchy and to express the interaction among objects.

5.0 TUTOR-MARKED ASSIGNMENT

1. Define the following
   a. Data Flow Diagram
   b. Data Dictionary
   c. Minispecification
2. Outline the problems with the top-down approach so prevalent in structured techniques as pointed out by Bertrand Meyer.

6.0 REFERENCES/FURTHER READING

Object-oriented Programming in C++. Nabajyoti Bark Kati,
Prentice-Hall of India Private Limited, New Delhi - 1 10 001, 2001.

MODULE 3 OBJECT-ORIENTED PROGRAMMING IN JAVA

UNIT 1 YOUR FIRST CUP OF JAVA

CONTENTS

1.0 INTRODUCTION

In this Unit you will start with a checklist of what you need to write your first and explanations of error messages you may encounter.

2.0 OBJECTIVES

After completing this Unit you should be able to:

- identify what you need to write your first java program
- create an application
- create an applet.

3.0 MAIN CONTENT

3.1 A Checklist

To write your first program, you need:

1. **The Java ™ 2 Platform, Standard Edition.** This is provided on the included CD-ROM. You can also download the SDK from http//java.sun.com/j2se/1.4/download.html and consult the installation instructions at http://java.sun.com/j2se/1.4/install-windows.html. (Make sure you download the SDK, not the JRE.)

2. **A text editor.** You can use EDIT provided on the included CD-ROM or Notepad, the simple editor included with the Windows platforms. To find Notepad, from the Start menu select Programs > Accessories > Notepad.

3.2 Creating Your First Application

Why Bytecodes are Cool

So, you've heard that with the Java programming language, you can "write once, run anywhere." This means that when you compile your program, you don't generate instructions for one specific platform. Instead, you generate Java bytecodes, which are instructions for the Java Virtual Machine (Java VM). If your platform--whether it's Windows, UNIX, MacOS, or an Internet browser--has the Java VM, it can understand those bytecodes.

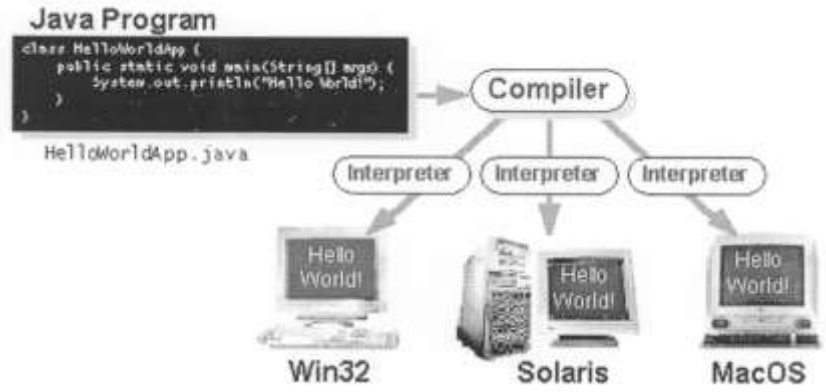
Your first program, Hello WORLDAPP!. To app, will simply display the greeting "Hello world!". To create this program, you will:

- **Create a source file.** A source file contains text, written in the Java programming language, that you and other programmers can understand. You can use any text editor to create and edit source files or use Notepad.

- **Compile the source file into a bytecode file.** The compiler, java, takes your source file and translates its text into instructions that the, Java Virtual Machine (Java VM) can understand. The compiler converts these instructions into a bytecode file.

Run the program contained in the bytecode file. The Java interpreter installed on your computer implements the Java VM. This interpreter takes your bytecode file and carries out the instructions by translating them into instructions that your computer can understand.

Class



a. Create a Source File.

To create a source file, you have two options:

- You can save the file HelloWorldApp. j ava (from the CD-ROM) on your computer and avoid a lot of typing. Then, you can go straight to step b.

- Or, you can follow these longer instructions:

1. Start NotePad or Edit (available on the CD). In a new document, type in the following code:

```
/**
* The HelloWorldApp class implements an application that
* displays "Hello World!" to the standard output
*/
public class HelloWorldApp {
public static void main(String[] args) {
// Display "Hello World!"
System. out. Println ("Hello World!");
```

Be Careful When You Type E

A ☐

a ☐

Type all code, commands, and file names exactly as shown. The Java compiler and interpreter are case sensitive, so you must capitalize consistently.

HelloWorldApp 7"- helloworldapp

2. Save this code to a file. If you are using Notepad, from the menu bar, select File > Save As. In the Save As dialog box:

- Using the Save in drop-down menu, specify the folder (directory) where you'll save your file. In this example, the directory is java on the C drive.
- In the File name text box, type "HelloWorldApp. java", including the double quotation marks.
- From the Save as type drop-down menu, choose Text Document.

When you're finished, the dialog box should look like this:

Now click Save, and exit Notepad.

b. **Compile the Source File.**

From the Start menu, select the MS-DOS Prompt application (Windows 95/98) or Command Prompt application (Windows NT). When the application launches, it should look like this:

The prompt shows your current directory. When you bring up the prompt for Windows 95/98, your current directory is usually WINDOWS on your C drive (as shown above) or WINNT for Windows

NT. To compile your source code file, change your current directory to the directory where your file is located. For example, if your source directory is java on the C drive, you would type the following command at the prompt and press Enter:

cd c:\java

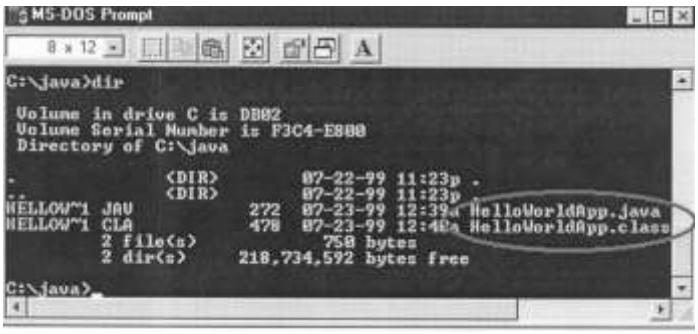
Now the prompt should change to C: \java>.

Note: To change to a directory on a different drive, you must type an extra
command.

C:\WINDOWS>cd d:\java
C:\WINDOWS>d:
D:\java>

As shown here, to change to the java directory on the D drive, you must reenter the drive, d:

If you enter dir at the prompt, you should see your file.



Now you can compile. At the prompt, type the following command and press Enter: Javac HelloWorldApp.java

If your prompt reappears without error messages, congratulations. You have successfully compiled your program.

Error Explanation

Bad command or file name (Windows 95/98)

The name specified is not recognized as an internal or external command, **operable program or batch file** (*Windows NT*)

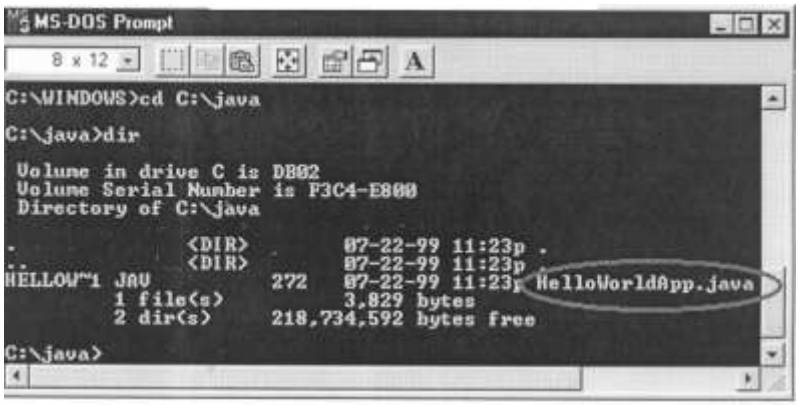
If you receive this error, Windows cannot find the Java compiler, Javac.

Here's one way to tell Windows where to find *Javac*. Suppose you installed the Java Software Development Kit in C: \jdkl . 4. At the prompt you would type the following command and press **Enter:**

C:\jdkl.4\bin\javac HelloWorldApp.java

Note: If you choose this option, each time you compile or run a program, you'll have to precede your javac and java commands with C : \jdkl . 4 \bin\..

The compiler has generated a Java bytecode tile, HelloWorldApp. class. At the prompt, type dir to see the new file that was generated



Now that you have a . class file, you can run your program.

c. Run the program

In the same directory, enter at the prompt:
Java HelloWorldApp

Now you should see:

result

Congratulations! Your program works.

Error Explanation

Exception in thread "main" java. lang.NoClassDefFoundError: HelloWorldApp

If you receive this error, java cannot find your bytecode file, HelloWorldApp . class.

One of the places j ava tries to find your bytecode file is your current directory. So, if your bytecode file is in C : \ j ava, you should change your current directory to that. To change your directory, type the following command at the prompt and press **Enter:**

cd c: \ java

The prompt should change to C : \java>. If you enter dir at the prompt, you should see your . java and. class files. Now enter java HelloWorldApp again.

If you still have problems, you might have to change your CLASSPATH variable. To see if this is necessary, try "clobbering" the classpath with the following command:

set CLASSPATH=

Now enter java HelloWorldApp again. If the program works now, you'll have to change your CLASSPATH variable.

Exercise 1.1:

When you compile a program written in the Java programming language, the compiler converts the human-readable source file into platform-independent code that a Java Virtual Machine can understand. What is this platform-independent code called?

Answer : Bytecode.

3.3 Creating Your First Applet

HelloWorldApp is an example of a Java application, a standalone program. Now you will create a Java applet called HelloWorld, which also displays the greeting "Hello world!". Unlike HelloWorldApp, however, the applet runs in a Java-enabled Web browser such as Hot Java, Netscape Navigator, or Microsoft Internet Explorer.

To create this applet, you'll perform the basic steps as before: create a Java source file; compile the source file; and run the program.

a. Create a Java Source File.

Again, you have two options:

- **You can save the files HelloWorld.java and Hello. html on your computer and avoid a lot of typing. Then, you can go straight to step b.**

- **Or, you can follow these instructions:**

1. Start NotePad. Type the following code into a new document:

```
import java. applet.*;
import java.awt.*;

        /**
* The HelloWorld class implements an applet that
* simply displays "Hello World!".

*/
public class HelloWorld extends Applet {
        public void paint(Graphics g) {
             // Display "Hello World!"
            g.drawString ("Hello world!", 50, 25);
```

Save this code to a file called HelloWorld. java.

2. You also need an HTML file to accompany your applet. Type the following code into a new Notepad document:

```
<HTML>
<HEAD>
<TITLE>A Simple Program</TITLE>
</HEAD>
<BODY>
Here is the output of my program:
<APPLET CODE="HelloWorld.class" WIDTH=150 HEIGHT=25>
</APPLET>
</BODY>
</HTML>
```

Save this code to a file called Hello. html.

b. Compile the Source File.

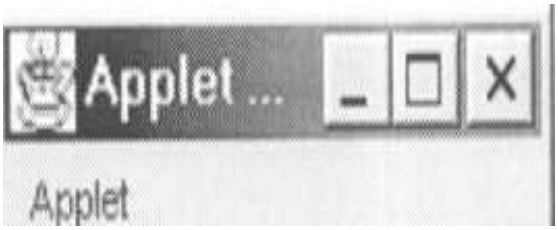
At the prompt, type the following command and press Return: javac HelloWorld.java

The compiler should generate a Java bytecode file, HelloWorld. class.

c. Run the Program.

Although you can view your applets using a Web browser, you may find it easier to test your applets using the simple application that comes with the Java TM Platform. To view the HelloWorld applet using appletviewer, enter at the prompt:

Appletviewer Hello.html
Now you should see:



Congratulations! Your applet works.

3.4 About The Java Technology

Java technology is both a programming language and a platform.

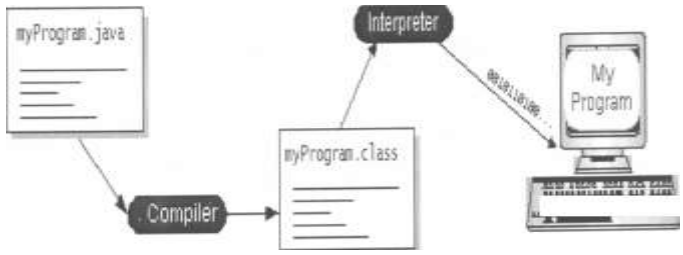
3.4.1 The Java Programming Language

The Java programming language is a high-level language that can be characterized by all of the following buzzwords:

• Simple	• Architecture neutral
• Object oriented	• Portable
• Distributed	• High performance
• Interpreted	• Multithreaded
• Robust Secure	• Dynamic

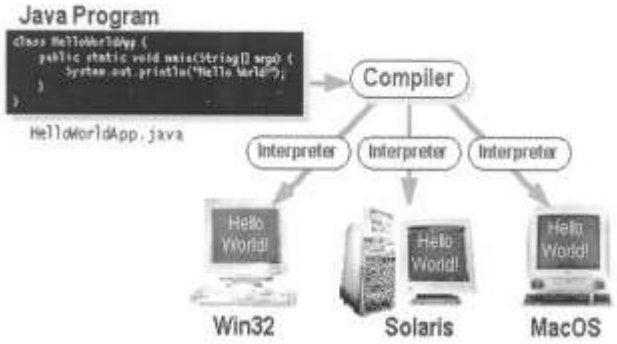
With most programming languages, you either compile or interpret a program so that you can run it on your computer. The Java programming language is unusual in that a program is both compiled and interpreted. With the compiler, first you translate a program into an intermediate language called Java bytecodes -the platform-independent

codes interpreted by the interpreter on the Java platform. The interpreter parses and runs each Java bytecode instruction on the computer. Compilation happens just once; interpretation occurs each time the program is executed. The following figure illustrates how this works.



You can think of Java bytecodes as the machine code instructions for the Java Virtual Machine (Java VM). Every Java interpreter, whether it's a development tool or a Web browser that can run applets, is an implementation of the Java VM.\

Java bytecodes help make "write once, run anywhere" possible. You can compile your program into bytecodes on any platform that has a Java compiler. The bytecodes can then be run on any implementation of the Java VM. That means that as long as a computer has a Java VM, the same program written in the Java programming language can run on Windows 2000, a Solaris workstation, or on an iMac.



3.4.2 The Java Platform

A platform is the hardware or software environment in which a program runs. 2000, Linux, Solaris, and MacOS. Most platforms can be described as a combination of the operating system and hardware. The Java platform differs from most other platforms in that it's a software-only platform that runs on top of other hardware-based platforms.

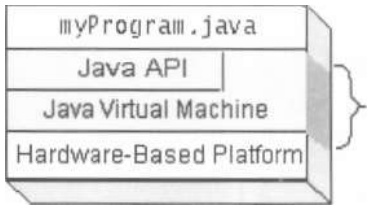
The Java platform has two components:

- The Java Virtual Machine (Java VM)
- The Java Application Programming Interface (Java API)

You've already been introduced to the Java VM. It's the base for the Java platform and is ported onto various hardware-based platforms.

The Java API is a large collection of ready-made software components that provide many useful capabilities, such as graphical user interface (GUI) widgets. The Java API is grouped into libraries of related classes and interfaces; these libraries are known as *packages.*

The following figure depicts a program that's running on the Java platform. As the figure shows, the Java API and the virtual machine insulate the program from the hardware.



Java Platform

Native code is code that after you compile it, the compiled code runs on a specific hardware platform. As a platform-independent environment, the Java platform can be a bit slower than native code. However, smart compilers, well-tuned interpreters, and just-in-time bytecode compilers can bring performance close to that of native code without threatening portability.

4.0 CONCLUSION

Now you have learned how to create your own Java application and your applet. You have learnt how to create a source code file for your application or applet, compile the source code into a bytecode file and run the program contained in the bytecode file.

5.0 SUMMARY

This unit as the title implies is a general introduction to the Java programming language and the Java platform. Subsequent units will go deeper into the characteristics, structure and use of the Java programming language.

6.0 REFERENCES/FURTHER READING

www.lava.sun.com/docs/books

UNIT 2 A CLOSER LOOK AT THE "HELLO WORLD" SAMPLE

CONTENTS

1.0 INTRODUCTION

The "Hello World" Application leads you through compiling and running a unit it also introduces some general Java techniques: how to define a class and how to use supporting classes and objects.

The "Hello World" Applet tells you how to compile and run an applet--a Java program to be included in HTML pages and executed in Java-enabled browsers. The lesson also introduces some general Java concepts and techniques: how to create a subclass, what packages are, and how to import classes and packages into a program.

This unit dissects the "Hello World" application and the "Hello World" applet that you've already seen.

2.0 OBJECTIVES

After completing this Unit you should be able to:

- define a class in java
- explain how the main method operates
- describe a package
- solve minor compiler and interpreter problems.

3.0 MAIN CONTENT

3.1 The "Hello World" Application

Now that you've seen a Java application (and perhaps even compiled and run it), you might be wondering how it works and how similar it is to other Java applications. Remember that a Java application is a standalone Java program-- a program written in the Java language that runs independently of any browser.

Here, again, is the code of the HelloWorld application

```
/**
* The HelloWorldApp class implements an application that
*  simply displays "Hello World!" to the standard output.
*/
class HelloWorldApp {
 public  static  void  main (String) {} arg) {
 system. Out. Println (“ Hello world )!” // Display the string
```

3.1.1 Comments in Java Code

The "Hello World" application has two blocks of comments. The first block, at the top of the program uses /** and * / delimiters. Later, a line of code is explained with a comment that's marked by / / characters. The Java language supports a third kind of comment, as well -- the familiar C-style comment, which is delimited with / * and * /.

The bold characters in the following listing are comments.

```
/**
* The HelloWorldApp class implements an application that
* simply displays "Hello World!" to the standard output.
*/
class HelloWorldApp {
        public static void main(String[] args) {
         System.out.println ("Hello    World!");
        //Display the string.
```

The Java language supports three kinds of comments:
/* text */
The compiler ignores everything from / * to * /.

/** documentation */
This indicates a documentation comment (doc comment, for short). The JDK javadoc tool uses doc comments when preparing automatically generated documentation.

// text
The compiler ignores everything from / / to the end of the line.

3.1.2 Defining a Class

In the Java language, each method (function) and variable exists within a class or an object (an instance of a class). The Java language does not support global functions or variables. Thus, the skeleton of any Java program is a class definition.

The first bold line in the following listing begins a class definition block.

```
/**
* The HelloWorldApp class implements an application that
* simply displays "Hello World!" to the standard output.
*/
class HelloWorldApp {

public static void main(String[] args) {
        System. out. Println ("Hello World!");    //Display the string.
```

A class--the basic building block of an object-oriented language such as Java--is a template that describes the data and behavior associated with instances of that class. When you instantiate a class you create an object that looks and feels like other instances of the same class. The data associated with a class or object is stored in variables; the behavior associated with a class or object is implemented with methods. Methods are similar to the functions or procedures in procedural languages such as C.
Julia Child's recipe for rack of lamb is a real-world example of a class. Her (While both
racks of lamb may "look and feel" the same, I imagine that they "smell and taste" different.)

A more traditional example from the world of programming is a class that represents a rectangle. The class would contain variables for the

origin of the rectangle, its width, and its height. The class might also contain a method that calculates the area of the rectangle. An instance of the rectangle class would contain the information for a specific rectangle, such as the dimensions of the floor of your office, or the dimensions of this page.

In the Java language, the simplest form of a class definition is

```
class name {
        . . .
}
```

The keyword class begins the class definition for a class named name. The variables and methods of the class are embraced by the curly brackets that begin and end the class definition block. The "Hello World" application has no variables and has a single method named main.

Exercise 2.1:
Which of the following is not a valid comment:

a./** comment * /
b. / * comment * /
c./* comment
d.// comment

Answer 2.1: c is an invalid comment.

3.1.3 The Main Method

The entry point of every Java application is its main method. When you run an application with the Java interpreter, you specify the name of the class that you want to run. The interpreter invokes the main method defined within that class. The main method controls the flow of the program, allocates whatever resources are needed, and runs any other methods that provide the functionality for the application.

The first bold line in the following listing begins the definition of a main method.

```
/**
* The HelloWorldApp class implements an application that
* simply displays "Hello World!" to the standard output.

class HelloWorldApp {
public static void main(String[] args) {
```

System.out.println ("Hello World!");
//Display the string.

Every Java application must contain a main method whose signature looks like this: public static void main(String[] args)

The method signature for the main method contains three modifiers:

- public indicates that the main method can be called by any object.
- static indicates that the main method is a class method.
- void indicates that the main method doesn't return any value.

3.1.3.1 How the main Method Gets Called

The main method in the Java language is similar to the main function in C and C++. When the Java interpreter executes an application (by being invoked upon the application's controlling class), it starts by calling the class's main method. The main method then calls all the other methods required to run your application.

If you try to invoke the Java interpreter on a class that does not have a main method, the interpreter refuse to run your program and displays an error message similar to this:

In class NoMain:void main (String argv [ ]) is not defined

3.1.3.2 Arguments to the main Method

As you can see from the following code snippet, the main method accepts a single argument: an array of elements of type String.
public static void main**(String[] args)**

This array is the mechanism through which the runtime system passes information to your application. Each String in the array is called a command-line argument. Command line arguments let users affect the operation of the application without recompiling it. For example, a sorting program might allow the user to specify that the data be sorted in descending order with this command-line argument:

-descending

The "Hello World" application ignores its command-line arguments, so there isn't much more to discuss here.

3.1.4 Using Classes and Objects

The other components of a Java application are the supporting objects, classes, methods, and Java language statements that you write to implement the application.

This section explains how the "Hello World" application uses classes and objects. If you aren't familiar with object-oriented concepts, then you might find this section confusing. If so, feel free to skip ahead to the next unit (Object-oriented programming concepts) and don't forget to return to finish this section.

The "Hello World" application is about the simplest Java program you can write that actually does something. Because it is such a simple program, it doesn't need to define any classes except for HelloWorld App. However, most programs that you write will be more complex and require you to write other classes and supporting Java code.
The "Hello World" application does use another class--the System class--that is part of the API (application programming interface) provided with the Java environment. The System class provides system-independent access to system-dependent functionality.

The bold code in the following listing illustrates the use of a class variable of the System class, and of an instance method.

```
/**
* The HelloWorldApp class implements an application that * simply displays "Hello World!" to the standard output.
*/
class HelloWorldApp {
          public static void main(String[} args)
            System.out.println("Hello World!");
//Display the string.
        }
}
```

3.1.4.1 Using a Class Method or Variable

Let's take a look at the first segment of the statement:
System.out.println("Hello World!");

The construct System. out is the full name of the out variable in the System class. Notice that the application never instantiates the System class and that out is referred to directly from the class name. This is because out is a class variable--a variable associated with the class

rather than with an instance of the class. You can also associate methods with a class--*class methods.*

To refer to class variables and methods, you join the class name and the name of the class method or class variable together with a period

3.1.4.2 Using an Instance Method or Variable

Methods and variables that are not class methods or class variables are known as instance methods and instance variables. To refer to instance methods and variables, you must reference the methods and variables from an object.

While System's out variable is a class variable, it refers to an instance of the Print Stream class (a class provided with the Java development environment) that implements the standard output stream.

When the System class is loaded into the application, it instantiates Print Stream and assigns the new Print Stream object to the out class variable. Now that you have an instance of a class, you can call one of its instance methods:

System.out.println ("Hello World!");
As you can see, you refer to instance methods and variables similarly to the way you refer to class methods and variables. You join an object reference (out) and the name of the instance method or variable (println) together with a period
The Java compiler allows you to cascade references to class and instance methods and variables together, resulting in constructs like the one that appears in the sample program:
System.out.println("Hello World!");

This line of code displays "Hello World!" to the application's standard output stream.

3.2 The "Helloworld" Applet

Now that you've seen a Java applet, you're probably wondering how it works. Remember that a Java applet is a program that adheres to a set of conventions that allows it to run within a Java-compatible browser.

Here again is the code for the "Hello World" applet.

```
import java.applet.Applet;
import java.awt.Graphics;
```

```
public class HelloWorld extends Applet {
        public void paint(Graphics g) {
            g.drawString("Hello world!", 50, 25);
```

3.2.1 Importing Classes and Packages

The code above starts off with two import statements. By importing classes or packages, a class can more easily refer to classes in other packages. In the Java language, packages are used to group classes, similar to the way libraries are used to group C functions.

The first two lines of the following listing import two classes used in the applet: Applet and Graphics.

```
import java.applet.Applet;
 import java.awt.Graphics;

public class HelloWorld extends Applet {
        public void paint(Graphics g) {
g.drawString("Hello world!", 50, 25);
          {
}
```

If you removed the first two lines, the applet could still compile and run, but only if you changed the rest of the code like this:

```
public class HelloWorld extends
        Java. applet. Applet {
         public void paint(java.awt.Graphics g) {
               g.drawString("Hello world!", 50, 25);
        }
}
```

As you can see, importing the Applet and Graphics classes lets the program refer to them later without any prefixes. The java. applet. and java. awt . prefixes tell the compiler which packages it should search for the Applet and Graphics classes. Both the java . app let and java . awt packages are part of the core Java API -- API that every Java program can count on being in the Java environment. The java. applet package contains classes that are essential to Java applets. The java . awt package contains the most frequently used classes in the Abstract Window Toolkit (AWT), which provides the Java graphical user interface (GUI).

You might have noticed that the Helloworldapp example uses the System class without any prefix, and yet does not import the System class. The reason is that the System class is part of the java. lang

package, and everything in the Java. lang package is automatically imported into every Java program.

Besides importing individual classes, you can also import entire packages. Here's an example:

```
import java. applet.*;
import java. awt.*;

public class HelloWorld extends Applet {
public void paint(Graphics g) {
        g.drawString("Hello world!", 50, 25);
          }
}
```

In the Java language, every class is in a package. If the source code for a class doesn't have a package statement at the top, declaring the package the class is in, then the class is in the default package. Almost all of the example classes in this unit are in the default package.

Within a package, all classes can refer to each other without prefixes. For example, the java. awt Component class refers to the java. awt Graphics class without any prefixes, without importing the Graphics class.

3.2.2 Defining an Applet Subclass

Every applet must define a subclass of the Applet class. In the "Hello World" applet, this subclass is called HeIloWorld. Applets inherit a great deal of functionality from the Applet class, ranging from communication with the browser to the ability to present a graphical user interface (GUI).
The first bold line of the following listing begins a block that defines the HelloWorld class.

```
import java. applet. Applet;
 import java.awt.Graphics;

public class HelloWorld extends Applet {
public void paint(Graphics g) {
g.drawString("Hello world!", 50, 25);
        }
}
```

The extends keyword indicates that HeIloWorld is a subclass of the class whose name follows: Applet. If the term subclass means nothing to

you, you'll learn about it soon in Object-Oriented Programming Concepts in Java.

From the Applet class, applets inherit a great deal of functionality. Perhaps most important is the ability to respond to browser requests. For example, when a Java-capable browser loads a page containing an applet, the browser sends a request to the applet, telling the applet to initialize itself and start executing.
An applet isn't restricted to defining just one class. Besides the necessary Applet use a class, the application that's executing the applet first looks on the local host for the class. If the class isn't available locally, it's loaded from the location that the Applet subclass originated from.

3.2.3 Implementing Applet Methods

The HelloWorld applet implements just one method, the paint method. Every applet must implement at least one of the following methods: init, start, or paint. Unlike Java applications, applets do not need to implement a main method.
The bold lines of the following listing implement the paint method.

```
import java.applet.Applet;
import java.awt.Graphics;

public class HelloWorld extends Applet {
        public void paint(Graphics g)
         g.drawString("Hello world!", 50, 25);
```

Every applet must implement one or more of the init, start, and paint methods.

Besides the init, start, and paint methods, applets can implement two more methods that the browser calls when a major event occurs (such as leaving the applet's page): stop and destroy. Applets can implement any number of other methods, as well.

Returning to the above code snippet, the Graphics object passed into the paint method represents the applet's onscreen drawing context. The first argument to the Graphics drawstring method is the string to draw onscreen. The second and third arguments are the (x,y) position of the lower left corner of the text onscreen. This applet draws the string "Hello world!" starting at location (50,25). The applet's coordinate system starts at (0,0), which is at the upper left corner of the applet's display area.

3.2.4 Running an Applet

Applets are meant to be included in HTML pages. Using the <APPLET> tag, you specify (at a minimum) the location of the Applet subclass and the dimensions of the applet's onscreen display area. When a Java-capable browser encounters an <APPLET> tag, it reserves onscreen space for the applet, loads the Applet subclass onto the computer the browser is executing on, and creates an instance of the Applet Subclass.

The bold lines of the following listing comprise the <APPLET> tag that includes the "Hello World" applet in an HTML page.

<HTML>
<HEAD>
<TITLE> A Simple Program </TITLE>
</HEAD>
<BODY>

Here is the output of my program:
<APPLET CODE="HelloWorld.class" WIDTH=150 HEIGHT=25>
</APPLET>
</BODY>
</HTML>

The above <APPLET> tag specifies that the browser should load the class whose compiled code is in the file named Hello World. Class. The browser looks for this file in the same directory as the HTML document that contains the tag.

When the browser finds the class file, it loads it over the network, if necessary, onto the computer the browser is running on. The browser then creates an instance of the class. If you include an applet twice in one page, the browser loads the class file once and creates two instances of the class.

The WIDTH and HEIGHT attributes are like the same attributes in an <IMG> tag: They specify the size in pixels of the applet's display area. Most browsers do not let the applet resize itself to be larger or smaller than this display area. For example, every bit of drawing that the "Hello World" applet does in its paint method occurs within the 150x25-pixel display area that the above <APPLET> tag reserves for it.

3.3 Solving Common Compiler and Interpreter Problems

If you're having trouble compiling your Java source code or running your application, this section might be able to help you. If nothing in this section helps, please refer to the documentation for the compiler or interpreter you're using.

Compiler Problems

Syntax Errors

If you mistype part of a program, the compiler may issue a syntax error. The message usually displays the type of the error, the line number where the error was detected, the code on that line, and the position of the error within the code. Here's an error caused by omitting a semicolon (;) at the end of a statement:

```
testing.java:14: ';' expected.
System.out.println("Input has " + count + " chars.")

1 error
```

Sometimes the compiler can't guess your intent and prints a confusing error message or multiple error messages if the error cascades over several lines. For example, the following code snippet omits a semicolon (;) from the bold line:

```
while (System.in.read() != -1)
    count++
System.out.println("Input has " + count + " chars.");
```

When processing this code, the compiler issues two error messages:

```
testing.java:13: Invalid type expression.
count++

testing.java:14: Invalid declaration.
        System.out.println("Input has " + count + " chars.");

2 errors
```

The compiler issues two error messages because after it processes count++, the compiler's state indicates that it's in the middle of an expression. Without the semicolon, the compiler has no way of knowing that the statement is complete.

If you see any compiler errors, then your program did not successfully compile, and the compiler did not create a . class file. Carefully verify the program, fix any errors that you detect, and try again.

Semantic Errors

In addition to verifying that your program is syntactically correct, the compiler checks for other basic correctness. For example, the compiler warns you each time you use a variable that has not been initialized:

```
testing.java:13: Variable count may not have been
initialized.
                count++

testing.java:l4: Variable count may not have been
 initialized.

System.out.println("Input has " + count + " chars.");

2 errors
```

Again, your program did not successfully compile, and the compiler did not create a . class file. Fix the error and try again.

Interpreter Problems

Can't Find Class

A common error of beginner Java programmers using the UNIX or Windows 95/NT JDK is to try to interpret the . class file created by the compiler. For example, if you try to interpret the file HelloWorldApp. class rather than the class HelloWorldApp, the interpreter displays this error message:

```
Can't find class HelloWorldApp.class
```

The argument to the Java interpreter is the name of the class that you want to use, not the filename.

The main Method Is Not Defined

The Java interpreter requires that the class you execute with it have a method named main, because the interpreter must have somewhere to begin execution of your Java application.

If you try to run a class with the Java interpreter that does not have a main method, the interpreter prints this error message:

```
In class classname:
```

void main(String argv[]) is not defined

In the above message, class name is the name of the class that you tried to run.

Changes to My Program Didn't Take Effect

Sometimes when you are in the edit/debug/run cycle, it appears that your changes to an application didn't take effect -- a print statement isn't printing, for example. This is common when running Java applications on MacOS using Java Runner. If you recompile a . class file, you must quit Java Runner and bring it up again, since Java Runner does not reload classes.

4.0 CONCLUSION

In this unit you have learned how to define a class and how to use supporting classes and objects. You have also learned how to create a subclass, what packages are, and how to import classes and packages into a program.

5.0 SUMMARY

You have learnt some general Java techniques in this unit, the subsequent units ill throw more light into these techniques.

6.0 TUTOR-MARKED ASSIGNMENT

1. Change the "HelloWorldApp.java" program so that it displays Hola Mundo! instead of Hello World!.

2. This modified version of HelloworldApp below has an error. Fix the error so that the program successfully compiles and runs. What was the error?

```
/**
 * The HelloWorldApp class implements an application that
 * simply displays "Hello World!" to the standard output.
 */
class HelloWorldApp {
    public static void main(String[] args) {
    System.out.println("Hello World!); //Display the string.
   }
}
```

3. How do you run an applet ?

7.0 REFERENCES/FURTHER READING

www."ava.sun.com/docs/books

UNIT 3 OBJECT-ORIENTED PROGRAMMING CONCEPTS IN JAVA

CONTENTS

1.0 INTRODUCTION

If you've never used an object-oriented language before, you need to understand the underlying concepts before you begin writing code. You need to understand what an object is, what a class is, how objects and classes are related, and how objects communicate by using messages. This unit describes the concepts behind object-oriented programming.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- define an object, class and message
- explain inheritance
- describe an interface

3.0 MAIN CONTENT

3.1 What Is an Object?

Objects are key to understanding object-oriented technology. You can look around you now and see many examples of real-world objects: your dog, your desk, your television set, your bicycle.

These real-world objects share two characteristics: They all have state and behavior. For example, dogs have state (name, color, breed, hungry)

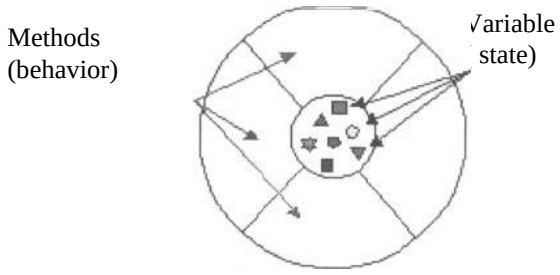
and behavior (barking, fetching, and wagging tail). Bicycles have state (current gear, current pedal cadence, two wheels, number of gears) and behavior (braking, accelerating, slowing down, changing gears).

Software objects are modeled after real-world objects in that they too have state and behavior. A software object maintains its state in one or more variables. A variable is an item of data named by an identifier. A software object implements its behavior with methods. A method is a function (subroutine) associated with an object.

Definition: An object is a software bundle of variables and related methods.

You can represent real-world objects by using software objects. You might want to represent real-world dogs as software objects in an animation program or a real-world bicycle as a software object in the program that controls an electronic exercise bike. You can also use software objects to model abstract concepts. For example, an event is a common object used in GUI window systems to represent the action of a user pressing a mouse button or a key on the keyboard.

The following illustration is a common visual representation of a software object:



Everything that the software object knows (state) and can do (behavior) is expressed by the variables and the methods within that object. A software object that modeled your real-world bicycle would have variables that indicated the bicycle's current state: its speed is 10 mph, its pedal cadence is 90 rpm, and its current gear is the 5th gear. These variables are formally known as instance variables because they contain the state for a particular bicycle object, and in object-oriented terminology, a particular object is called an instance.

Exercise 3.1

Software objects are modeled after real-world objects in that they too have state behaviour. How doe software objects maintain their state and implement them behavior?

In addition to its variables, the software bicycle would also have methods to brake, change the pedal cadence, and change gears. (The bike would not have a method for changing the speed of the bicycle, as the bike's speed is just a side effect of what gear it's in, how fast the rider is pedaling, whether the brakes are on, and how steep the hill is.) These methods are formally known as instance methods because they inspect or change the state of a particular bicycle instance.

The object diagrams show that the object's variables make up the center, or nucleus, of the object. Methods surround and hide the object's nucleus from other objects in the program. Packaging an object's variables within the protective custody of its methods is called encapsulation. This conceptual picture of an object-a nucleus of variables packaged within a protective membrane of methods-is an ideal representation of an object and is the ideal that designers of object-oriented systems strive for. However, it's not the whole story. Often, for practical reasons, an object may wish to expose some of its variables or hide some of its methods. In the Java programming language, an object can specify one of four access levels for each of its variables and methods. The access level determines which other objects and classes can access that variable or method. Encapsulating related variables and methods into a neat software bundle is a simple yet powerful idea that provides two primary benefits to software developers:

- Modularity: The source code for an object can be written and maintained independently of the source code for other objects. Also, an object can be easily passed around in the system. You can give your bicycle to someone else, and it will still work.

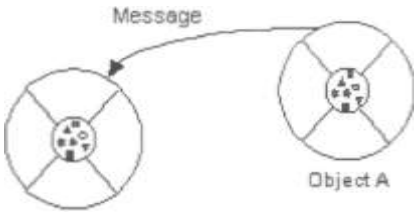
- Information hiding: An object has a public interface that other objects can use to communicate with it. The object can maintain private information and methods that can be changed at any time without affecting the other objects that depend on it. You don't need to understand the gear mechanism on your bike to use it.

3.2 What Is a Message?

A single object alone is generally not very useful. Instead, an object usually appears as a component of a larger program or application that

contains many other objects. Through the interaction of these objects, programmers achieve higher-order functionality and more complex behavior. Your bicycle hanging from a hook in the garage is just a bunch of titanium alloy and rubber; by itself, the bicycle is incapable of any activity. The bicycle is useful only when another object (you) interacts with it (pedal).

Software objects interact and communicate with each other by sending messages to each other. When object A wants object B to perform one of B's methods, object A sends a message to object B



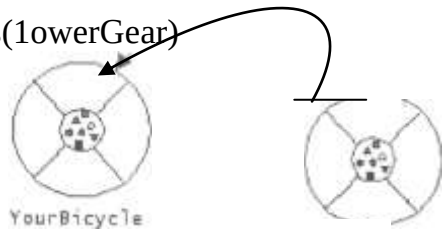
Object B

Sometimes, the receiving object needs more information so that it knows exactly what to do; for example, when you want to change gears on your bicycle, you have to indicate which gear you want. This information is passed along with the message as parameters.

The next figure shows the three components that comprise a message:

l. The object to which the message is addressed (Your Bicycle)
2. The name of the method to perform (change Gears)
3. Any parameters needed by the method (lower Gear)

change Gears(1owerGear)



you

These three components are enough information for the receiving object to perform the desired method. No other information or context is required.

Messages provide two important benefits.

- An object's behavior is expressed through its methods, so (aside from direct variable access) message passing supports all possible interactions between objects.

- Objects don't need to be in the same process or even on the same machine to send and receive messages back and forth to each other.

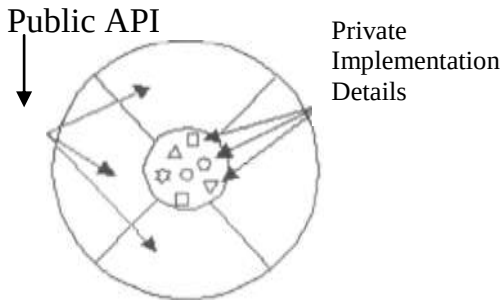
3.3 What Is a Class?

In the real world, you often have many objects of the same kind. For example, your bicycle is just one of many bicycles in the world. Using object-oriented terminology, we say that your bicycle object is an instance of the class of objects known as bicycles. Bicycles have some state (current gear, current cadence, two wheels) and behavior (change gears, brake) in common. However, each bicycle's state is independent of and can be different from that of other bicycles.

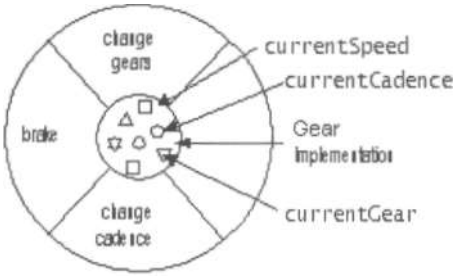
When building bicycles, manufacturers take advantage of the fact that bicycles share characteristics, building many bicycles from the same blueprint. It would be very inefficient to produce a new blueprint for every individual bicycle manufactured.

In object-oriented software, it's also possible to have many objects of the same kind that share characteristics: rectangles, employee records, video clips, and so on. Like the bicycle manufacturers, you can take advantage of the fact that objects of the same kind are similar and you can create a blueprint for those objects. A software blueprint for objects is called a class.

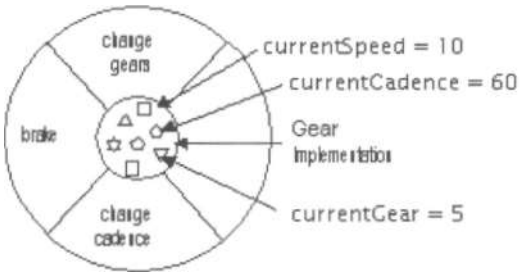
Definition: A class is a blueprint, or prototype, that defines the variables and the methods common to all objects of a certain kind.



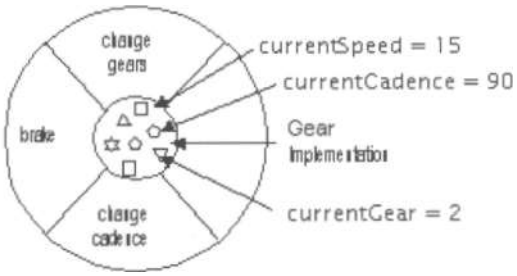
The class for our bicycle example would declare the instance variables necessary to contain the current gear, the current cadence, and so on, for each bicycle object. The class would also declare and provide implementations for the instance methods that allow the rider to change gears, brake, and change the pedaling cadence, as shown in the next figure.



After you've created the bicycle class, you can create any number of bicycle enough memory for the object and all its instance variables. Each instance gets its own copy of all the instance variables defined in the class.

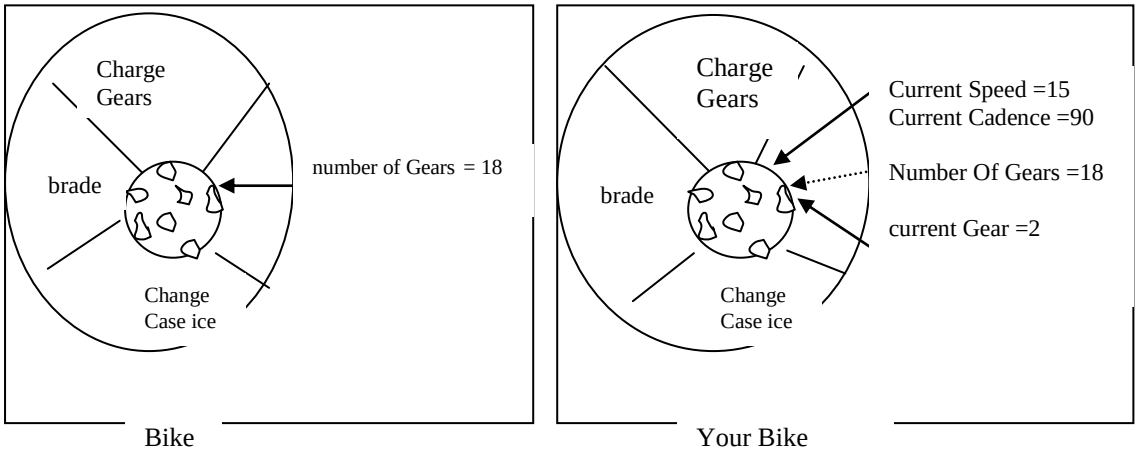


My Bike



YourBike

In addition to instance variables, classes can define class variables. A class variable contains information that is shared by all instances of the class. For example, suppose that all bicycles had the same number of gears. In this case, defining an instance variable to hold the number of gears is inefficient; each instance would have its own copy of the variable, but the value would be the same for every instance. In such situations, you can define a class variable that contains the number of gears. All instances share this variable. If one object changes the variable, it changes for all other objects of that type. A class can also declare class methods. You can invoke a class method directly from the class, whereas you must invoke instance methods on a particular instance.



Class **Instance of a Class**

3.4 Objects vs. Classes

You probably noticed that the illustrations of objects and classes look very similar. And indeed, the difference between classes and objects is often the source of some confusion. In the real world, it's obvious that classes are not themselves the objects they describe: A blueprint of a bicycle is not a bicycle. However, it's a little more difficult to differentiate classes and objects in software. This is partially because software objects are merely electronic models of real-world objects or abstract concepts in the first place. But it's also because the term "object" is sometimes used to refer to both classes and instances.

In the figures, the class is not shaded, because it represents a blueprint of an object rather than an object itself. In comparison, an object is shaded, indicating that the object exists and that you can use it.

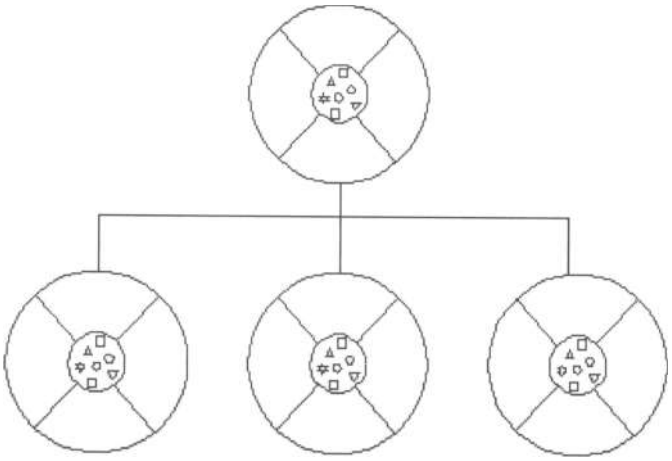
3.5 What Is Inheritance?

Generally speaking, objects are defined in terms of classes. You know a lot about an object by knowing its class. Even if you don't know what a penny-farthing is, if I told you it was a bicycle, you would know that it had two wheels, handle bars, and pedals.

Object-oriented systems take this a step further and allow classes to be defined in terms of other classes. For example, mountain bikes, racing bikes, and tandems are all kinds of bicycles. In object-oriented

terminology, mountain bikes, racing bikes, and tandems are all *subclasses* of the bicycle class. Similarly, the bicycle class is the superclass of mountain bikes, racing bikes, and tandems. This relationship is shown in the following figure.

Bicycle



Mountain Bike Racing Bike Tandem Bike

Each subclass inherits state (in the form of variable declarations) from the superclass. Mountain bikes, racing bikes, and tandems share some states: cadence, speed, and the like. Also, each subclass inherits methods from the superclass. Mountain bikes, racing bikes, and tandems share some behaviors: braking and changing pedaling speed, for example.

However, subclasses are not limited to the state and behaviors provided to them by their superclass. Subclasses can add variables and methods to the ones they inherit from the superclass. Tandem bicycles have two seats and two sets of handle bars; some mountain bikes have an extra set of gears with a lower gear ratio.

Subclasses can also override inherited methods and provide specialized implementations for those methods. For example, if you had a mountain bike with an extra set of gears, you would override the "change gears" method so that the rider could use those new gears.

You are not limited to just one layer of inheritance. The inheritance tree, or class hierarchy, can be as deep as needed. Methods and variables are inherited down through the levels. In general, the farther down in the hierarchy a class appears, the more specialized its behavior.

The object class is at the top of class hierarchy, and each class is its descendant (directly or indirectly). A variable of type Object can hold a reference to any object, such as an instance of a class or an array. Object provides behaviors that are required of all objects running in the Java Virtual Machine. For example, all classes inherit Object's to String method, which returns a string representation of the object.

Inheritance offers the following benefits:

- Subclasses provide specialized behaviors from the basis of common elements provided by the superclass. Through the use of inheritance, programmers can reuse the code in the superclass many times.

- Programmers can implement super classes called abstract classes that define "generic" behaviors. The abstract superclass defines and may partially implement the behavior, but much of the class is undefined and unimplemented. Other programmers fill in the details with specialized subclasses.

3.6 What Is an Interface?

In English, an interface is a device or a system that unrelated entities use to interact. According to this definition, a remote control is an interface between you and a television set, the English language is an interface between two people, and the protocol of behavior enforced in the military is the interface between people of different ranks. Within the Java programming language, an interface is a device that unrelated objects use to interact with each other. An interface is probably most analogous to a protocol (an agreed on behavior). In fact, other object-oriented languages have the functionality of interfaces, but they call their interfaces protocols.

The bicycle class and its class hierarchy defines what a bicycle can and cannot do in terms of its "bicycle ness." But bicycles interact with the world on other terms. For example, a bicycle in a store could be managed by an inventory program. An inventory program doesn't care what class of items it manages as long as each item provides certain information, such as price and tracking number. Instead of forcing class relationships on otherwise unrelated items, the inventory program sets up a protocol of communication. This protocol comes in the form of a set of constant and method definitions contained within an interface. The inventory interface would define, but not implement, methods that set and get the retail price, assign a tracking number, and so on.

To work in the inventory program, the bicycle class must agree to this protocol by implementing the interface. When a class implements an interface, the class agrees to implement all the methods defined in the interface. Thus, the bicycle class would provide the implementations for the methods that set and get retail price, assign a tracking number, and so on.

You use an interface to define a protocol of behavior that can be implemented by any class anywhere in the class hierarchy. Interfaces are useful for the following:

- Capturing similarities among unrelated classes without artificially forcing a class relationship.

- Declaring methods that one or more classes are expected to implement.

- Revealing an object's programming interface without revealing its class.

4.0 CONCLUSION

You now know what objects are. How objects communicate through messages and how objects differ from classes. You have learned how classes can be defined in terms of other classes through inheritance. You have also learned how unrelated classes communicate with each other in the Java language through interfaces.

5.0 SUMMARY

In this unit, you have learned about object-oriented concepts. The next unit will explain how these concepts translate into Java codes.

6.0 TUTOR-MARKED ASSIGNMENT

1. Software objects interact and communicate with each other by sending messages to each other, Explain.
2. Differentiate between Objects and Classes.

7.0 REFERENCES/FURTHER READING

www.lava.sun.com/docs/books

UNIT 4 TRANSLATING CONCEPTS INTO CODE

CONTENTS

1.0 INTRODUCTION

Now that you have a conceptual understanding of object-oriented programming let's look at how these concepts get translated into code.

This unit looks at a small applet, and shows you the code that creates objects, implements classes, sends messages, establishes a superclass, and implements an interface.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- identify objects in an applet
- identify classes in an applet
- identify messages in an applet
- identify inheritance in an applet
- identify interfaces in an applet

3.0 MAIN CONTENT

3.1 Clickme Applet

The ClickMe applet is a relatively simple program and the code for it is short. However, if you don't have much experience with programming, you might find the code daunting. I don't expect you to understand everything in this program right away, and this unit won't explain every

detail. The intent is to expose you to some source code and to associate it with the concepts and terminology you just learned.

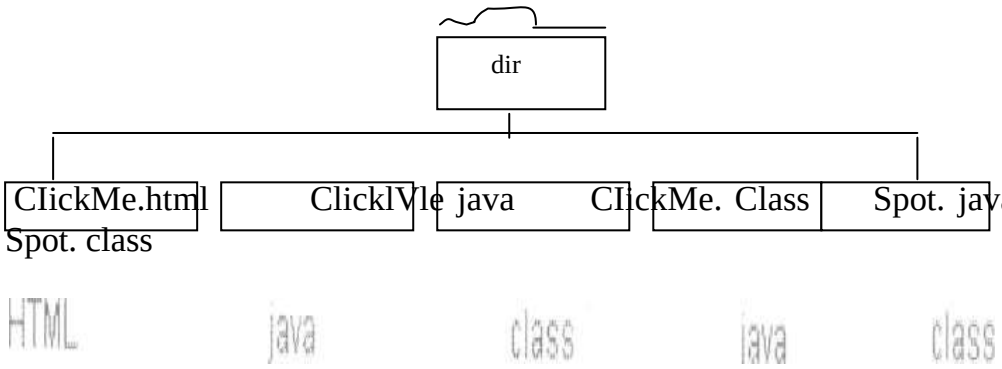
The Source Code and the Applet Tag for ClickMe

To compile this applet you need two source files: ClickMe . java and Spot.
java. (they are provided in the Clickme directory of your CD)

To run the applet you need to create an html file with this applet tag in it: (it is also provided in the Clickme directory of your CD)

```
<applet code="ClickMe.class"
        width="300" height="150">
 </applet>
```

Then load the page into your browser or the appletviewer tool. Make sure all the necessary files are in the same directory. (all the file are already in the ClickMe directory on your CD)



Note: If you're having problems running this example:

- Make sure you copy both Spot. java and Click Me . java and place them in the same directory (the files are already in the CIickMe directory on your CD).

- If you can compile one file but not the other, you probably have a CLASSPATH problem. If ". " (indicating your current directory) isn't in your class path, the ClickMe class can't find the Spot class, even though they are in the same directory. Try unsetting CLASSPATH and recompiling, like this:

  - set CLASSPATH=
  - javac ClickMe.java

If your problem is fixed, then you should modify your global CLASSPATH variable to add ". " to it.

3.2 Objects in the CIickMe Applet

Many objects play a part in this applet. The two most obvious ones are the ones you can see: the applet itself and the spot, which is red on-screen.

The browser creates the applet object when it encounters the applet tag in the HTML code containing the applet. The applet tag provides the name of the class from which to create the applet object. In this case, the class name is ClickMe..

The Clickme.applet in turn creates an object to represent the spot on the screen. Every time you click the mouse in the applet, the applet moves the spot by changing the object's x and y location and repainting itself. The spot does not draw itself; the applet draws the spot, based on information contained within the spot object.

Besides these two obvious objects, other, nonvisible objects play a part in this applet. Three objects represent the three colors used in the applet (black, white, and red); an event object represents the user action of clicking the mouse, and so on.

3.3 Classes in the ClickMe Applet

Because the object that represents the spot on the screen is very simple, let's look at its class, named Spot. It declares three instance variables: size contains the spot's radius, x contains the spot's current horizontal location, and y contains the spot's current vertical location:

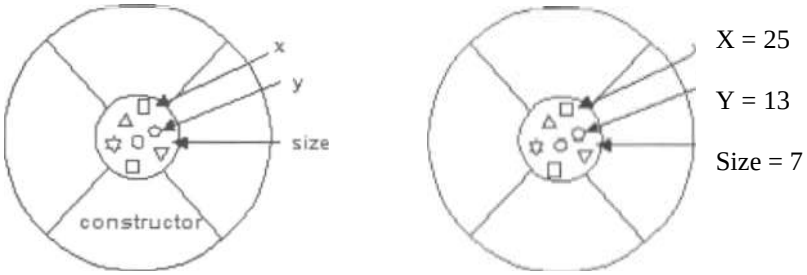
```
public class Spot {
     //instance variables
public int size;
public int x, y;

//constructor
public Spot(int intSize) {
size = intSize;
x    = 1
y    = 1;
            }
}
```

Additionally, the class has a constructor -- a subroutine used to initialize new objects created from the class. You can recognize a constructor because it has the same name as the class. The constructor initializes all three of the object's variables. The initial value of size is provided as an argument to the constructor by the caller. The x and y variables are set to –one indicating that the spot is not on-screen when the applet starts up.

The applet creates a new spot object when the applet is initialized. Here's the relevant code from the applet class:

```
private Spot spot = null;
private static final int RADIUS = 7;
…...
spot = new Spot(RADIUS);
```

The first line shown declares a variable named spot whose data type is Spot, the class from which the object is created, and initializes the variable to null. The second line declares an integer variable named RADIUS whose value is 7. Finally, the last line shown creates the object; new allocates memory space for the object. Spot (RADIUS) calls the constructor you saw previously and passes in the value of RADIUS. Thus the spot object's size is set to 7



The figure on the left is a representation of the Spot class. The figure on the right is a spot object.

3.4 Messages in the CIickMe Applet

As you know, object A can use a message to request that object B do something, and a message has three components:

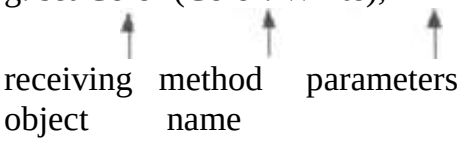
1. The object to which the message is addressed
2. The name of the method to perform
3. Any parameters the method needs

Here are two lines of code from the Click Me applet:

```
g.setColor(Color.white);
g.fillRect(0, 0, getSize().width - 1, getSize().height - 1);
```

Both are messages from the applet to an object named g--a Graphics object that knows how to draw simple on-screen shapes and text. This object is provided to the applet when the browser instructs the applet to draw itself. The first line sets the color to white; the second fills a rectangle the size of the applet, thus painting the extent of the applet's area white.

The following figure highlights each message component in the first message:



3.5 Inheritance in the ClickMe Applet

To run in a browser, an object must be an applet. This means that the object must be an instance of a class that derives from the Applet class provided by the Java platform.

The ClickMe applet object is an instance of the ClickMe class, which is declared like this:

```
public class ClickMe extends Applet implements
Mouse Listener {
```

The extends Applet clause makes ClickMe a subclass of Applet. ClickMe inherits a lot of capability from its superclass, including the ability to be initialized, started, and stopped by the browser, to draw within an area on a browser page, and to register to receive mouse events. Along with these benefits, the ClickMe class has certain obligations: its painting code must be in a method called paint, its initialization code must be in a method called init, and so on.

```
public void init() {
... // C1ickMe's initialization code here
}
public void paint(Graphics g) {
    ... // ClickMe's painting code here
 }
```

3.6 Interfaces in the ClickMe Applet

The ClickMe applet responds to mouse clicks by displaying a red spot at the click location. If an object wants to be notified of mouse clicks, the Java platform event system requires that the object implement the Mouse Listener interface. The object must also register as a mouse listener.

The Mouse Listener interface declares five different methods each of which is called for a different kind of mouse event: when the mouse is clicked, when the mouse moves outside of the applet, and so on. Even though the applet is interested only in mouse clicks it must implement all five methods. The methods for the events that it isn't interested in are empty.

The complete code for the ClickMe applet is shown below. The code that participates in mouse event handling is bold:

```
import java.applet.Applet;
import java.awt.*;
import java.awt.event.*;

public class ClickMe extends Applet implements MouseListener {
 private Spot spot = null;
 private static final int RADIUS = 7;

public void init() {
 addMouseListener(this);

}
public void paint(Graphics g) {
// draw a black border and a white background
  g.setColor (Color.white);
          g.fillRact 0, 0, getSize().width -1,        getSize () height

              - 1) ;
                    g.setColor(Color.black);
                    g.drawRect(0,  0,  getSize().width  –  1,1,
              - 1) ;
                    // draw the spot
                    g. setColor (Color. Red);
```

```
                    If  ( spot ! = null){
                    g.fillOval (spot.x - RADIUS,
                    spot.y - RADIUS,
                    (RADIUS * 2, RADIUS * 2);
                      }

                     }

public void mousePressed(MouseEvent event)
{ if (spot == null) {
      spot = new Spot(RADIUS);
}
                        spot.x = event.getX();
                        spot.y = event.getY();
                        repaint();
            }
            public    void    mouseClicked(MouseEvent event) {}
            public    void    mouseReleased(MouseEvent event) {}
            public    void    mouseEntered(MouseEvent event) {}
            public    void    mouseExited(MouseEvent event) {}
```

3.7 API Documentation

The C1ickMe applet inherits a lot of capability from its superclass. To learn more about how ClickMe works, you need to learn about its superclass, Applet. How do you find that information? You can find detailed descriptions of every class in the API documentation, which constitute the specification for the classes that make up the Java platform.

The API documentation for the Java 2 Platform is online at java. sun. com.

4.0 CONCLUSION

This discussion glossed over many details and left some things unexplained, but you should have some understanding now of what object-oriented concepts look like in code. You should now have a general understanding of the following:

- That a class is a prototype for objects
- That objects are created from classes
- That an object's class is its type
- How to create an object from a class
- What constructors are
- How to initialize objects

- What the code for a class looks like
- What class variables and methods are
- What instance variables and methods are

5.0 SUMMARY

In this unit, you have learned how to identify objects, classes, messages, inheritance, interfaces in an applet.

6.0 REFERENCES/FURTHER READING

www.lava.sun.com/docs/books

UNIT 5 JAVA LANGUAGE BASICS 1 (VARIABLES & OPERATORS)

CONTENTS

1.0 INTRODUCTION

The BasicsDemo program that follows adds the numbers from I to 10 and displays the **result.**

```
public class BasicsDemo {
        public static void main(String} args) {
          int sum = 0;
                  for (int current = 1; current <= 10;
          current++) {
                          sum += current;
                    }
                     System.out.println ("Sum = " + sum);
                  }
        }
```

The output from this program is:

```
Sum = 55
```

Even a small program such as this uses many of the traditional features of the Java programming language, including variables, operators, and control structures. The code might look a little mysterious now. But this unit teaches what you need to know about the nuts and bolts of the Java programming language to understand this program.

2.0 OBJECTIVES

After this unit, you should be able to:

- define a variable.
- describe data types
- list the different primitive data types in java
- determine the right data type to use for each variable declaration

3.0 MAIN CONTENT

3.1 Variables

An object stores its state in variables.

Definition: A variable is an item of data named by an identifier.

You must explicitly provide a name and a type for each variable you want to use in your program. The variable's name must be a legal identifier --an unlimited series of Unicode characters that begins with a letter. You use the variable name to refer to the data that the variable contains. The variable's type determines what values it can hold and what operations can be performed on it. To give a variable a type and a name, you write a variable declaration, which generally looks like this:

type name

In addition to the name and type that you explicitly give a variable, a variable has scope. The section of code where the variable's simple name can be used is the variable's scope. The variable's scope is determined implicitly by the location of the variable declaration, that is, where the declaration appears in relation to other code elements.

The MaxVariableDemo program, show below declares eight variable of different
types within its main method. The variable declarations are bold:

```
public class MaxVariablesDemo {
    public static void main(String args      ⊏ )⊐

        // integers
        byte largestByte = Byte.MAX_VALUE;
```

```
        short larggestshort  = short. MAX VALUE;
        int largestinteger  = Integer. MAX_ VALUE
        long largestlong = long. MAX_ VALUE

        // real numbers
        float  largestFloat = Float. MAX_VALUE
        double largestDouble = Double. MAX_ VALUE

        // other primitive types
         char  aChar =’S’;
         boolean aBoolean = true;

// display them all
     System.out.println                largest   byte value     Is  ”     +
     largestByte);
     System.out.println                largest   short value    Is   ”     +
     largestShort);
     System.out.println          ("The largest   integer value Is   ”      +
     largest Integer);
     System.out.println                largest   long value     Is   ”       +
     largestLong);
     System.out.println          ("The largest   float value     Is  ”       +
     largest Float);
     System.out.println          ("The largest   double value  Is  ”       +
     largestDouble);

if    (Character.isUpperCase (aChar)) {
       System.out.println ("The character   ” + aChar +  ” is
Upper  case .”);
} else {
System.out.println ("The character  “ + aChar +  “ is
        Lower case.”);
                 }
                system. Out. Println ) “ the value of aBoolean is “ +
aBoolean);
        }
}
```

The output from this program is:

```
The     largest byte value is 127
The     largest short value is 32767
        The     largest integer value is 2147483647
The     largest long value is 9223372036854775807
The     largest float value is 3.40282e+38
The     largest double value is 1.79769e+308
The      character S is upper case.
```

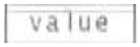
The value of aBoolean is true

The following sections elaborate on the various aspects of variables, including data types, names, scope, initialization, and final variables. The MaxVariablesDemo program uses two items with which you might not yet be familiar and are not covered in this unit: several constants named MAX VALUE and an if-else statement. Each MAX VALUE constant is defined in one of the number classes provided by the Java platform and is the largest value that can be assigned to a variable of that numeric type.

3.1.1 Data Types

Every variable must have a data type. A variable's data type determines the values that the variable can contain and the operations that can be performed on it. For example, in the MaxVariablesDemo program, the declaration int largestInteger declares that largestInteger has an integer data type (int). Integers can contain only integral values (both positive and negative). You can perform arithmetic operations, such as addition, on integer variables.

The Java programming language has two categories of data types: primitive and reference. A variable of primitive type contains a single value of the appropriate size and format for its type: a number, a character, or a boolean value. For example, an integer value is 32 bits of data in a format known as two's complement, the value of a char is 16 bits of data formatted as a Unicode character, and so on.

VariableName 

The following table lists, by keyword, all of the primitive data types supported by Java, their sizes and formats, and a brief description of each. The MaxVariablesDemo program declares one variable of each primitive type.
Primitive Data Types

Primitive Data Types

Keyword	**Description**	**Size/Format**	
(integers)			
Byte	Byte-length integer	8-bit	two's complement
Short	Short Integer	16-bit	two's complement
Int	integer	32-bit	two's

		complement
Long	Long integer	64- bit two's complement
(real numbers)		
Float	Single- precision floating point	32-bit IEEE 754
Double	Double - precision floating point	64-bit IEEE 754
(other types)		
Chart	A single character	16-bit Unicode character
Boolean	A Boolean value (true or false	True or dales

Tip: In other languages, the format and size of primitive data types may depend on the platform on which a program is running. In contrast, the Java programming language specifies the size and format of its primitive data types. Hence, you don't have to worry about system-dependencies.

You can put a literal primitive value directly in your code. For example, if you need to assign the value 4 to an integer variable you can write this:

int anInt = 4;

The digit 4 is a literal integer value. Here are some examples of literal values of various primitive types:

Examples of Literal Values and Their Data Types

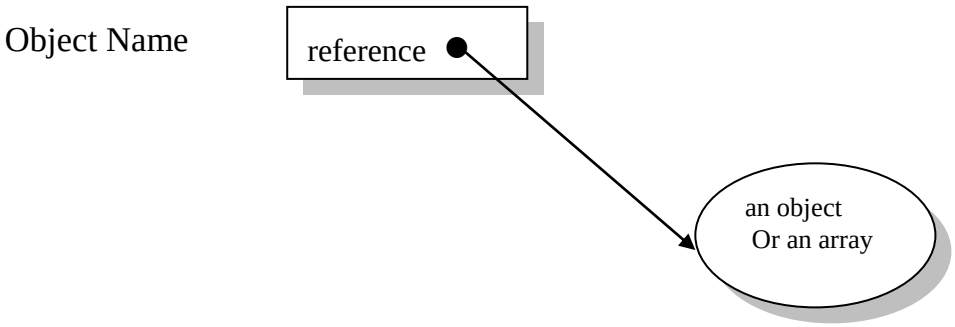
Literal	Date Type
178	int
8864L	Long
37. 266	Double
37.266D	Double
87. 363F	Float
26.77e3	Double
'c'	Char
True	Boolean
False	Boolean

Generally speaking, a series of digits with no decimal point is typed as an integer. You cab specify a long integer by putting an 'L' or 'I' after the number. 'L' is preferred as it cannot be confused with the digit ' 1 ' . A series of digits with a decimal point is of type double. You can

specify a float by putting an ' f' or ' F' after the number. A literal character value is any single Unicode character between single quote marks. The two boolean literals are simply true and false.

Arrays, classes, and interfaces are reference types. The value of a reference type variable, in contrast to that of a primitive type, is a reference to (an address of) the value or set of values represented by the variable.

A reference is called a pointer, or a memory address in other languages. The Java programming language does not support the explicit use of addresses like other languages do. You use the variable's name instead.



3.1.2 Variable Names

A program refers to a variable's value by the variable's name. For example, uses the name largestByte. A name, such as largestByte, that's composed of a single identifier, is called a simple name. Simple names are in contrast to qualified names, which a class uses to refer to a member variable that's in another object or class.

In the Java programming language, the following must hold true for a simple name:

1. It must be a legal identifier. An identifier is an unlimited series of Unicode characters that begins with a letter.

2. It must not be a keyword, a boolean literal (true or false), or the reserved word null.

3. It must be unique within its scope. A variable may have the same name as a variable whose declaration appears in a different scope. In some situations, a variable may share the same name as another variable if it is declared within a nested block of code. (We will cover this in the next section, Scope.)

By Convention : Variable names begin with a lowercase letter, and class names words are joined together, and each word after the first begins with an uppercase letter, like this: isVisible. The underscore character (_) is acceptable anywhere in a name, but by convention it is used only to separate words in constants (because constants are all caps by convention and thus cannot be case-delimited).

3.1.3 Scope

A variable scope is the region without which the variable can be referred to by its simple name. Secondarily, scope also determines when the system creates and destroys memory for the variable. Scope is distinct from visibility, which applies only to member variables and determines whether the variable can be used from outside of the class within which it is declared. Visibility is set with an access modifier.

The location of the variable declaration within your program establishes its scope and places it into one of these four categories:

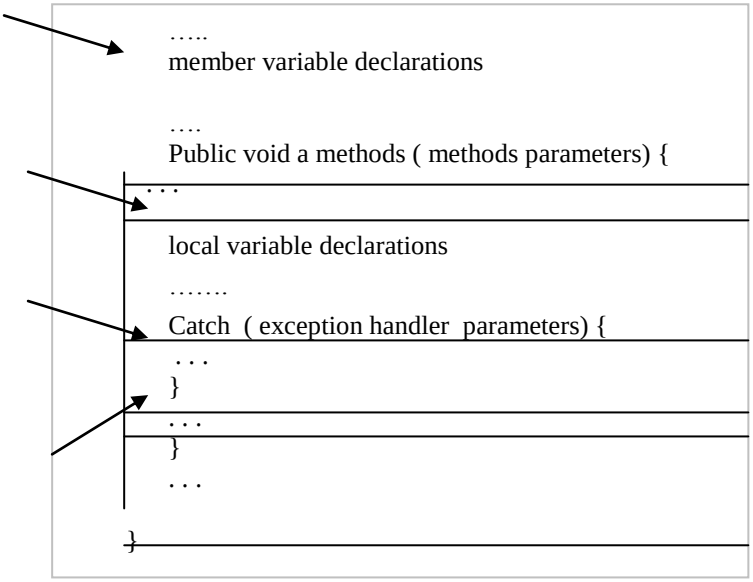
- Member variable
- Local variable
- method parameter
- exception-handler parameter

member variable scope

method Parameter Scope

Local Variable Scope

Exception Handier Parameter Scope



A member variable is a member of a class or an object. It is declared within a class but outside of any method or constructor. A member variable's scope is the entire declaration of the class. However, the declaration of a member needs to appear before it is used when the use is in a member initialization expression.

You declare local variables within a block of code. In general, the scope of a local variable extends from its declaration to the end of the code block in which it was declared. In MaxVariableDemo, all of the variables declared within the main method are local variables. The scope of each variable in that program extends from the declaration of the variable to the end of the main method --indicated by the first right curly bracket } in the program code.

Parameters are formal arguments to methods or constructors and are used to pass values into methods and constructors. The scope of a parameter is the entire method or constructor for which it is a parameter.

Exception-handler parameters are similar to parameters but are arguments to an exception handler rather than to a method or a constructor. The scope of an exception-handler parameter is the code block between { and } that follow a catch statement.

Consider the following code sample:

```
if (...) {
        int i = 17;
        . . .
       }
System. out. println("The value of i = " + i);
// error
```

The final line won't compile because the local variable i is out of scope. The scope of i is the block of code between the { and } . The i variable does not exist anymore after the closing} . Either the variable declaration needs to be moved outside of the *if* statement block, or the println method call needs to be moved into the *if* statement block.

3.1.4 Variable Initialization

Local variables and member variables can be initialized with an assignment statement when they're declared. The data type of the variable must match the data type of the value assigned to it. The MaxVariableDemo program provides initial values for all its local

variables when they are declared. The local variable declarations from that program follow, with the initialization code set in **bold:**

```
// integers
        byte largestByte = Byte.MAX_VALUE;
  short largestShort = Short.MAX_VALUE;
        int largestInteger = Integer.MAX_VALUE;
         long largestLong = Long.MAX VALUE;

// real numbers
   float largestFloat = Float.MAX_VALUE;
  double largestDouble = Double.MAX VALUE;

// other primitive types
         char aChar = 'S'; boolean aBoolean = true;
```

Parameters and exception-handler parameters cannot be initialized in this way. The value for a parameter is set by the caller.

3.2 Operators

An operator performs a function on one, two, or three operands. An operator that requires one operand is called a unary operator. For example, ++ is a unary operator that increments the value of its operand by 1. An operator that requires two operands is a binary operator . For example, = is a binary operator that assigns the value from its righthand operand to its left-hand operand. And finally, a ternary operator is one that requires three operands. The Java programming language has one ternary operator, ? :, which is a short-hand i f -e 1 s e statement.

The unary operators support either prefix or postfix notation. Prefix notation means that the operator appears before its operand:

```
operator op          //prefix notation
```

Postfix notation means that the operator appears after its operand:

```
op operator          //postfix notation
```

All of the binary operators use infix notation, which means that the operator appears between its operands:

```
opl operator op2     //infix notation
```

The ternary operator is also infix; each component of the operator appears between operands:

opl ? opt : op3 //infix notation

In addition to performing the operation, an operator returns a value. The return value and its type depend on the operator and the type of its operands. For example, the arithmetic operators, which perform basic arithmetic operations such as addition and subtraction, return numbers- the result of the arithmetic operation. The data type returned by an arithmetic operator depends on the type of its operands: If you add two integers, you get an integer back. An operation is said to evaluate to its result.

Though there are other types of operators in Java, you will learn about three categories in this unit.

- Arithmetic Operators
- Relational and Conditional Operators
- Assignment Operators

3.2.1 Arithmetic Operators

The Java programming language supports various arithmetic operators for all floating point and integer numbers. These operators are + (addition), - (subtraction)*, (multiplication), / (division), and % (modulo).

The following table summarizes the binary arithmetic operations in the Java programming language.

Operator	Use		Description
+	Op1 Op2	+	Adds op1 and op2
_	Op1 Op2	_	Subtract op2 from op1
*	Op1 Op2	x	Multiplies op1 by op2
/	Op1 Op2	/	Divides op1 by op2
%	Op1 Op2	%	Computers the remainder of dividing op1 op2

Here's an example program, ArithmeticDemo, that defines two double-precision floating-point numbers and uses the five arithmetic operators to perform different arithmetic operations. This program also uses + to concatenate strings. The arithmetic operations are shown in **bold:**

```
public class ArithmeticDemo {
        public static void main(String[ ] args) {

//a few numbers
int i = 37;

int j = 42;
double x = 27.475;
double y = 7.22;
System.out.println("Variable values...");
System.out.println ("          i   = ” + i);
System.out.println ("   j   =  ” +j);
System.out.println ("   x  =  ” +x);
System.out.println ("   y  =  ” +y);

// adding numbers
system. Out. Println {“ Adding … “);
system. Out. Println {“ i  + j  = “ +  ( i + j));
system. Out. Println (“ x + y = “ + ( x + y));


//subtracting number
system .  out. Println (“ Subtracting …”);
System,. Out println  (“ i  - j = “ + ( i – j ));
System. Out. Println  (“ x –y = “ + ( x – y));

//multiplying numbers
 System.out.println("Multiplying...");
System.out.println(" i * j = " + (i * j));
System.out.println(" x * y = " + (x * Y));

//dividing numbers
System.out.println("Dividing...");
System.out.println(" i / j = " + (i/j));
        ystem.out.println("   x / y = " + (x/y));

//computing the remainder resulting from dividing nos
System.out.println("Computing the remainder...");
System.out.println(" i % j = " + (I  %j));
System.out.println(" % y = " + (x%Y));
```

```
//mixing types
System.out.println("Mixing types...");
System.out.println(" j + y = " + (j + Y));
System.out.println(" i * x = " + (i * x));
        }

    }
```

The output from this program is:

```
Variable values...
i = 37
j = 42
x = 27.475
          = 7.22
Adding...
i + j = 79
x + y = 34.695
Subtracting...
i - j = -5
x - y = 20.255
Multiplying...
i * j = 1554
x * y = 198.37
 Dividing...
i / j = 0
x / y = 3.8054
Computing the remainder..
i %  j = 37
x % y = 5.815
Mixing types...
j + y = 49.22
i * x = 1016.58
```

Note that when an integer and a floating-point number are used as operands to a single arithmetic operation, the result is floating point. The integer is implicitly converted to a floating-point number before the operation takes place. The following table summarizes the data type returned by the arithmetic operators, based on the data type of the operands. The necessary conversions take place before the operation is performed.

Data Type of result	Data Type of Operands
Long	Neither operand is a float or a double (integer arithmetic); at least one operand is a long.
Int	Neither operand is a float or a double (integer arithmetic): neither operand is a long.
Double	At least one operand is a double.
Float	At least one operand is a float; neither operand is a double

3.2.2 Relational and Conditional Operators

A relational operator compares two values and determines the relationship between them. For example, ! = returns true if the two operands are unequal. This table summarizes the relational operators:

Operator	Use	Returns true if
>	Op1 > op2	Op1 is grater than op2
>=	Op1 >= Op2	Op1 is greater than or equal op2
<	Op1	Op1 is less than op2
<=	Op1 <= Op2	Op1 is less than or equal to op2
= =	Op1 = = Op2	Op1 and op2 are equal
! =	Op1 != Op2	Op1 and op2 are not equal

Following is an example, RelationaDemo, that defines three integer numbers and uses the relational operators to compare them. The relational operations are shown in bold:

```
public class RelationalDemo {
public static void main(String[] args) {

                    //a   few   Numbers
                    int   i =    37;
                    int   j =    42;
                    int   k =   42:
System.out.println("Variable values…" ) ;
System.out.println(" i = " + i);
System.out.println(" j = " + j) ;
System.out.println(" k = " + k);
//  greater than
          system. Out. Println (" Greater than …");
          System . out println (" I > J = " + (I>J));
//false
          system.. out println (" j > I = " +  ( j > I ));
// true
          system . out. Println ( "  k > j = " + ( k > j));
// false, they are equal

// greater than or equal to
          system.. out. Println (" Greater  than or equal to … ");
          system.out println (" I . >= j = " + ( I >= j));
// false
          system. out. Println (" j .= I = " + (j >= i));
// true
          system. out. Println ( " k >= j = " + (k >= j));
// true

// less than
          system. out. Println (" less than…");
          system. out println (" I < j = " + (I < j));
// true
          system. out println ( " j < I = " + ( j < i));
// false
          system. .out. println ( " k < j = " + (k < j));

// false
// Less  than or  equal to
          system. out. Println (" less than or equal to …");
          system. out println ("  I <= j = " + (i<=j));
// true
          system .out . println  (" j <= I = " + ( j<=i);
// false
          system.out . println  (" k <= j = " + (k <= j));
//true
```

```
// equal to
        system. out. Println ( " Equal to … ");
        system. out println ("  k = = j = " + (k = = j));
//true
        system.out. println (" k != j = " + (k !=j));
// false
                }
        }
```

Here's the output from this program:
Variable values...
i = 37
j = 42
k = 42

Greate			than	false
i	>	¡	=	
¡	>	i	=	true
k	>	¡	=	false

Greater than or equal to.
i >= j = false
j >= i = true
k >= j = true
Less than...
i < j = true
j < i = false
k < j = false
Less than or equal to.
i <= j = true
j <= i = false
k <= j = true
Equal to ...
i == j = false
k == j = true
Not equal to ...
i != j = true
k != j = false

Relational operators often are used with conditional operators to construct more complex decision-making expressions. The Java programming language supports six conditional operators-five binary and one unary--as shown in the following table.

Operator	Use	Returns true if
&&	Op1 && Op2	opl and op2 are both true, conditionally evaluates op2
I I	Op1 I I Op2	either opl or op2 is true, conditionally evaluates op2
!	! op	Op is false
&	Op1 & Op2	opl and op2 are both true, always evaluates op1 and op2
I	Op1 I Op2	either opl or op2 is true, always evaluates opl and op
	Op1 ^ Op2	if opI and op2 are different--that is if one or the other of the operands is true but not both

One such operator is &&, which performs the conditional AND operation. You can use two different relational operators along with & & to determine whether both relationships are true. The following line of code uses this technique to determine whether an array index is between two boundaries. It determines whether the index is both greater than or equal to 0 and less than NUM ENTRIES, which is a previously defined constant value.

0 <= index && index < NUM_ ENTRIES

Note that in some instances, the second operand to a conditional operator may not be evaluated. Consider this code segment:

(numChars < LIMIT) && (...)

The && operator will return true only if both operands are true. So, if numChars is greater than or equal to LIMIT, the left-hand operand for & & is f a l se, and the return value of && can be determined without evaluating the right-hand operand. In such a case, the interpreter will not evaluate the right-hand operand. This has important implications if the right-hand operand has side effects, such as reading from a stream, updating a value, or making a calculation.

When both operands are boolean, the operator & performs the same operation as &&. However, & always evaluates both of its operands and returns true if both are true. Likewise, when the operands are boolean, I performs the same operation as I I . The operator always evaluates both of its operands and returns true if at least one of its operands is true.

When their operands are numbers, & and I perform bitwise manipulations.

3.2.3 Assignment Operators

You use the basic assignment operator, =, to assign one value to another. The MaxvariableDemo, program uses = to initialize all of its local variables:

```
// integers
        byte largestByte = Byte.MAX_VALUE;
  short largestShort /= Short.MAX VALUE;
  int largestInteger = Integer.MAX VALUE;
 long largestLong /= Long.MAX_VALUE;
// real numbers
float largestFloat /= Float.MAX VALVE;
 double         largestDouble = Double. MAX _ VALUE;
 // other primitive types
    char aChar = ' s';
boolean aBoolean = true;
```

The Java programming language also provides several shortcut assignment operators t hat allow you to perform an arithmetic, shift, or bitwise operation and an assignment operation all with one operator. Suppose you wanted to add a number to a variable and assign the result back into the variable, like this:

```
        i = i + 2;
```

You can shorten this statement using the shortcut operator +=, like this:

```
 i += 2;
```

The two previous lines of code are equivalent.
The following table lists the shortcut assignment operators and their lengthy equivalents:

Operator	Use	Equivalent to
+=	Op1 += op2	op1 = op1 + op2
-=	Op1 -= op2	op1 = op1 – op2
*=	Op1 *= op2	op1 =op1 * op2
/=	Op1 /= op2	op1 =op1 / op2
%=	Op1 %= op2	op1 =op1 %& op2
&=	Op1 &= op2	op1 =op1 & op2
I=	Op1 I = op2	op1 =op1 I op2
^=	Op1 ^= op2	op1 =op1 ^ op2
<<=	Op1 <<= op2	op1 =op1 << op2

>>=	Op1 >>= op2	op1 =op1 >>op2
>>>=	Op1 >>>=op2	op1 =op1 >>> op2

4.0 CONCLUSION

Variables and operators are essential part of a language that cannot be overlooked. They are the bits and pieces that form the basis from which programs are developed. Understanding a programming language involves a good understanding of these building blocks. It has been clearly demonstrated that there is virtually nothing a programmer can do without using the legal variable name, comparing values using the appropriate operator, and placing them where they ought to be.

5.0 SUMMARY

When you declare a variable, you explicitly set the variable's name and data type. The Java programming language has two categories of data types: primitive and reference. A variable of primitive type contains a value.

The location of a variable declaration implicitly sets the variable's scope, which determines what section of code may refer to the variable by its simple name. There are four categories of scope: member variable scope, local variable scope, parameter scope, and exception-handler parameter scope.

You can provide an initial value for a variable within its declaration by using the assignment operator (=).

You can declare a variable as final. The value of a final variable cannot change after it's been initialized.

6.0 TUTOR-MARKED ASSIGNMENT

1. Which of the following are valid variable names?
   a. Int
   b. AnInt
   c. I
   d. i1
   e. 1
   f. thingl
   g. lthing
   h. ONE-HUNDRED
   i. ONE_ HUNDRED

j. something2do

2. Answer the following questions about the Ba s i c s Demo program.
   a. What is the name of each variable declared in the program? Remember that method parameters are also variables.
   b. What is the data type of each variable?
   c. What is the scope of each variable?

3. Consider the following code snippet:
   int i = 10;
   int n = i++o5;

   i. What are the values of i and n after the code is executed?

   ii. What are the final values of i and n if instead of using the postfix increment operator (i++), you use the prefix version (++i))?

4. What is the value of i after the following code snippet executes?
   int i = 8;
   i >>=2 ;

5. What is the value of i after the following code snippet executes?
   int i = 17;
   i >>=1;

6. Write a program that calculates the number of US dollars equivalent to a given number of French francs. Assume an exchange rate of 6.85062 francs per dollar.

7.0 REFERENCES/FURTHER READING

http://www.java.sun.com

UNIT 6 JAVA LANGUAGE BASICS 2 (EXPRESSIONS AND STATEMENTS)

CONTENTS

1.0 INTRODUCTION

Variables and operators, which you met in the previous unit, are basic building blocks of programs. You combine literals, variables, and operators to form expressions- segments of code that perform computations and return values. Certain expressions can be made into statements-complete units of execution. By grouping statements together with curly braces { and }, you create blocks of code.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define expressions and statements
- describe how control structures are used in java programming
- use block statements
- control programming sequence in loops.

3.0 MAIN CONTENT

3.1 Expressions

Expressions perform the work of a program. Among other things, expressions are used to compute and to assign values to variables and to help control the execution flow of a program. The job of an expression

is twofold: to perform the computation indicated by the elements of the expression and to return a value that is the result of the computation.

Definition: An expression is a series of variables, operators, and method calls (constructed according to the syntax of the language) that evaluates to a single value.

As discussed in the previous unit, operators return a value, so the use of an operator is an expression. This partial listing of the MaxVariablesDemo program shows some of the program's expressions in bold:

```
…
// other primitive types
char aChar = 'S';
boolean aBoolean = true;

// display them all
System.out.println ("The largest byte value is " +
largestByte);
…

if (Character.isUpperCase(aChar)) {
…
}
```

Each of these expressions performs an operation and returns a value.

Expression	**Action**	**Value Returned**
aChar = ' S'	Assign the character 'S' to The character variable aChar	the value of aChar after the assignment ('S')
"The largest byte value + largestByte	Concatenate the string “The largest byte value is > and the value of largestByte converted to a sting	The resulting string: the largest byte value is 127
Character. isUpperCase (aChar	Call the method'isUpperCase	" The return value ot the method: true

The data type of the value returned by an expression depends on the elements used in the expression. The expression aChar = ' S' returns a character because the assignment operator returns a value of the same data type as its operands and aChar and ' S' are characters. As you see from the other expressions, an expression can return a boolean value, a string, and so on.

The Java programming language allows you to construct compound expressions and statements from various smaller expressions as long as the data types required by one part of the expression matches the data types of the other. Here's an example of a compound expression:

In this particular example, the order in which the expression is evaluated is unimportant because the results of multiplication is independent of order--the outcome is always the same no matter what order you apply the multiplications. However, this is not true of all expressions. For example, the following expression gives different results depending on whether you perform the addition or the division operation first:

```
x + y / 100             //ambiguous
```

You can specify exactly how you want an expression to be evaluated by using balanced parentheses (and) . For example to make the previous expression unambiguous, you could write:

```
(x + y)/ 100            //unambiguous, recommended
```

If you don't explicitly indicate the order in which you want the operations in a compound expression to be performed, the order is determined by the precedence assigned to the operators in use within the expression. Operators with a higher precedence get evaluated first. For example, the division operator has a higher precedence than does the addition operator. Thus, the two following statements are equivalent:

```
x + y / 100
x + (y / 100) //unambiguous, recommended
```

When writing compound expressions, you should be explicit and indicate with parentheses which operators should be evaluated first. This will make your code easier to read and to maintain.

The following table shows the precedence assigned to the operators. The operators in this table are listed in precedence order: the higher in the table an operator appears, the higher its precedence. Operators with

higher precedence are evaluated before operators with a relatively lower precedence. Operators on the same line have equal precedence.

Postfix operator	[ ] . (params) expre++ expr--
Unary operator	++expr - -expr =expr – expr~!
Creation or cast	New (type) expr
Multiplicative	* / %
Additive	+ -
Shift	<< >> >>>
Relational	< > <= >= instance of
Equality	= = !=
Bitwise AND	&
Bitwise exclusion OR	ˆ
Bitwise inclusive OR	I
Logical AND	&&
Logical OR	II
Conditional	?
Assignment	= += -= *= /= %= &= ˆ= I= <<= >>= >>>=

When
operators of equal precedence appear in the same expression, a rule must govern which is evaluated first. All binary operators except for the assignment operators are evaluated in left-to-right order. Assignment operators are evaluated right to left.

3.2 Statements

Statements are roughly equivalent to sentences in nature languages.
A statement forms a complete unit of execution. The following types of expressions can be made into a statement by terminating the expression with a semicolon (;):

- Assignment expressions
- Any use of ++ or –
- Method calls
- Object creation expressions

These kinds of statements are called expression statements. Here are some examples of expression statements:

```
aValue          =       8933.234;
//assignment  statement

aValue++;
//increment statement
```

```
System.out.println(aValue);
 //method call statement
Integer integerobject = new Integer(4);
 //object creation statement
```

In addition to these kinds of expression statements, there are two other kinds of statements. A declaration statement declares a variable. You've seen many examples of declaration statements.

```
double aValue = 8933.234;                    //
 declaration statement
```

A control structure regulates the order in which statements get executed. The for loop and the i f statement are both examples of control structures.

3.3 Blocks

A block is a group of zero or more statements between balanced braces and can be used anywhere a single statement is allowed. The following listing shows two blocks from the MaxVariablesDemo_program, each containing a single statement:

```
if (Character.isUpperCase(aChar)) {
   System.out.println("The character “ + a char +
"  is upper case.");
}  else (
   System.out.println("The character “ + aChar +
" is lower case.");
        }
```

3.4 Control Structures

When you write a program, you type statements into a file. Without control structures, the interpreter executes these statements in the order they appear in the file from left to right, top to bottom. You can use control structures in your programs to conditionally execute statements, to repeatedly execute a block of statements, and to otherwise change the normal, sequential flow of control. For example, in the following code snippet, the i f statement conditionally executes the System. out. println statement within the braces, based on the return value of Character. isUpperCase (aChar)

```
char c;
…
if (Character.isUpperCase(aChar)) {
 System.out.println("The character " + aChar +
```

```
 " is upper case.");
}
```

The Java programming language provides several control structures, which are listed in the following table.

Statement Type	Keyword
Looping	While, do- while, for
Decision	If else, switch- case
Exception handling	Try- catch – finally, throw
Branching	Break, continue, label:, return

In this course material we will only discuss the first two: Looping and Decision making.

The while and do-while Statements

You use a *while* statement to continually execute a block of statements while a condition remains true. The general syntax of the while statement is:

```
while (expression) {
      statement
}
```

First , the while statement evaluates expression, which must return a boolean value. if the expression returns true, then the while statement executes the statement(s) associated with it. The while statement continues testing the expression and executing its block until the expression returns false.

The example program shown below, called While Demo, uses a while statement to step through the characters of a string, appending each character from the string to the end of a string buffer until it encounters the letter g.

```
public class WhileDemo {
      public static void main(String[ ] args) {

String copyFromMe = "Copy this string until you " +
                          "encounter the letter 'g'.";
```

```
StringBuffer copyToMe = new StringBuffer();

          int i = 0;
char c = copyFromMe.charAt(i);

while (c != 'g') {
        copyToMe.append(c);
        c = copyFromMe.charAt(++i);
 }
            {System.out.println(copyToMe);
```

The value printed by the last line is: Copy this strin.

The Java programming language provides another statement that is similar to the while statement--the (do-while statement. The general syntax of the do-while is:

```
do {

Statement (s)
} while (expression);
```

Instead of evaluating the expression at the top of the loop, do-while evaluates the expression at the bottom. Thus the statements associated with a do-while are executed at least once.

Here's the previous program rewritten to use do-while and renamed to DoWhileDemo:

```
public class DoWhileDemo {
       public static void main(String[largs) {

String copyFromMe = "Copy this string until you " +
                                "encounter the letter 'g'.";
StringBuffer copyToMe = new StringBuffer();

int i = 0;
char c = copyFromMe.charAt(i);

do {
copyToMe.append(c);
c = copyFromMe.charAt(++i);
} while (c != 'g'); System.out.println(copyToMe);
}
```

The value printed by the last line is: Copy this strain.

The for Statement

The *for*- statement provides a compact way to iterate over a range of values. The general form of the for statement can be expressed like this:

```
for (initialization; termination; increment) {
        statement
}
```

The initialization is an expression that initializes the loop-it's executed once at the beginning of the loop. The termination expression determines when to terminate the loop. This expression is evaluated at the top of each iteration of the loop. When the expression evaluates to false, the loop terminates. Finally, increment is an expression that gets invoked after each iteration through the loop. All these components are optional. In fact, to write an infinite loop, you omit all three expressions:

```
for ( ; ; ) {      // infinite loop
…
}
```

Often for loops are used to iterate over the elements in an array, or the over the elements of an array and print them:

```
public class ForDemo {
  public static void main(String[ ] args) {
         int[ ] arrayofInts = { 32, 87, 3, 589, 12, 1076,
         2000, 8, 622, 127 };

for (int i = 0; i < array0fInts.length; i.++)
{ Sys tem. out .print (arrayofIrits [ i ]       +

System.out.println();
  }
}
```

The output of the program is:32 87 3 589 12 1076
2000 8 622 127.

Note that you can declare a local variable within the initialization expression of a for loop. The scope of this variable extends from its declaration to the end of the block governed by the for statement so it can be used in the termination and increment expressions as well. If the variable that controls a for loop is not needed outside of the loop, it's best to declare the variable in the initialization expression. The names i, j, and k are often used to control for loops; declaring them within the for loop initialization expression limits their life-span and reduces errors.

The if else Statements

The if statement enables your program to selectively execute other statements, based on some criteria. For example, suppose that your program prints debugging information, based on the value of a boolean variable named DEBUG. If DEBUG is true, your as x. might
program prints debugging information, such as the value of a variable, such Otherwise, your program proceeds normally. A segment of code to implement this look like this:

```
if (DEBUG) {
System.out.println("DEBUG: x = " + x);
}
```

This is the simplest version of the if statement: The executed if a condition is true. Generally, the simple form of if can be written like this:

```
If (expression) {
statement (s)
```

What if you want to perform a different set of statements if the expression is false? You use the else statement for that. Consider another example. Suppose that your program needs to perform different actions depending on whether the user clicks the OK button or another button in an alert window. Your program could do this by using an i f statement along with an else statement:

```
// response is either OK or CANCEL depending
// on the button_ that the user pressed
…
if (response == OK) {
// code to perform OK action}
else {
// code to perform Cancel action
}
```

The else block is executed if the i f part is false. Another form of the else statement, else if, executes a statement based on another expression. An if statement can have any number of companion else i f statements but only one else. Following is a program, IFELseDemo, that assigns a grade based on the value of a test score: an A for a score of 90% or above, a B for a score of 80% or above, and so on:

```
public class IfElseDemo {
public static void main(String[] args) {

int testscore = 76;
```

```
char grade;

if (testscore >= 90) {
 grade = 'A';

        } else if (testscore >=        80) {
        grade = 'B';
        } else if (testscore >=        70) {
        grade = 'C';
        } else if (testscore >=        60) {
grade = 'D'; } else {
 grade = 'F';
System.out.println("Grade+ grade) ;
```

The output from this program is:
Grade = C

You may have noticed that the value of test score can satisfy more than one of the expressions in the compound i f statement: 76 >= 70 and 76 >= 60. However, as the runtime system processes a compound i f statement such as this one, once a condition is satisfied, the appropriate statements are executed (grade = ' C' and control passes out of the i f statement without evaluating the remaining conditions.

The Java programming language supports an operator, ? :, that is a compact version of an if statement. Recall this statement from the Max Variables Demo program:

```
If ( character . I Upper case (achar) ){
} else {
        System.out.println("The character” + aChar +
" is lower case.");
}
```

Here's how you could rewrite that statement using the ? : operator:

```
System.out.println("The character " + aChar + " is " +
(Character.isUpperCase(aChar) ? "upper" "lower") + "case.");
```

The ? : operator returns the string "upper" if the isUpperCase method returns true. Otherwise, it returns the string "lower". The result is concatenated with other parts of a message to be displayed. Using ? : makes sense here because the i f statement is secondary to the call to the println method. Once you get used to this construct, it also makes the code easier to read.

The switch Statement

Use the switch statement to conditionally perform statements based on an integer expression. Following is a sample program, Switch Demo, that declares an integer named month whose value supposedly represents the month in a date. The program displays the name of the month, based on the value of month, using the switch statement:

```
public class SwitchDemo {
    public static void main(String[] args) {

int month = 8
switch  (month) {
case 1: System.out.println("January"); break;
case 2: System.out.println("February"); break;
case 3: System.out.println("March"); break;
case4: System.out.println("April"); break;
case 5: System.out.println("May"); break;
 case 6: System.out.println("June"); break;
case 7: System.out.println("July"); break;
case 8: System.out.println("August"); break; break;
case 9: System.out.println("September");
case 10: System.out.println("October"); break ;
case 11:system .outprintln("November"); break ;
case12: System. out. printlin ("December"); break
}
}
}
```

The switch statement evaluates its expression, in this case the value executes the appropriate caw statement. Thus, the output of the program course, you could implement this by using an i f statement:

```
int month = 8;
if (month == 1)
System.out.println("January");
 }else if (month == 2)
 { System.out.println("February");
 }
… // and so on
```

Deciding whether to use an if statement or a switch statement is a judgment call. You can decide which to use, based on readability and other factors. An if statement can be used to make decisions based on ranges of values or conditions, whereas a switch statement can make decisions based only on a single integer value. Also, the value provided to each case statement must be unique.

Another point of interest in the switch statement is the break statement after each case. Each break statement terminates the enclosing switch statement, and the flow of control continues with the first statement following the switch block. The break statements are necessary because without them, the case statements fall through. That is, without an explicit break, control will flow sequentially through subsequent case statements. Following is an example, SwitchDemo2, which illustrates why it might be useful to have case statements fall through:

```
public class SwitchDemo2 {
     public static void main(String[] args) {

int month = 2;
int year = 2000;
int numDays = 0;

switch (month)
{ case 1:
case 3:
case 5:
 case 7:
case 8:
case 10:
 case 12:

     numDays = 31;
     break;
case 4:
case 6:
case 9:
case 11:
   numDays = 30;
   break;
case 2:
      if (((year % 4 == 0) && !(year % 100 == 0))
    11 (year % 400 == 0) )
        numDays = 29;
       else
     numDays = 28; break;
System.out.println("Number of Days = " + numDays);
   }
}
```

The output from this program is:

```
 Number of Days = 29
```

Technically, the final break is not required because flow would fall out of the switch statement anyway. However, we recommend using a break for the last case statement just in case you need to add more case statements at a later date. This makes modifying the code easier and less error-prone.
Finally, you can use the default statement at the end of the switch to handle all values that aren't explicitly handled by one of the case statements.

```
int month = 8;
        . . .
switch (month) {

        case  1:   System.out.println("January"); break;
        case  2:   System.out.println("February"); break;
        case  3:   System.out.println("March"); break;
        case  4:   System.out.println("April"); break;
        case  5:   System.out.println("May"); break;
        case  6:   System.out.println("June"); break;
        case  7:   System.out.println("July"); break;
        case  8:   System.out.println("August"); break;
        case  9:   System.out.println("September"); break;
        case  10:  System.out.println("October"); break;
        case  11:  System.out.println("November"); break;
        case  12:  System.out.println("December"); break;

          default: System.out.println("Hey, that's not a valid month!");
break;

        }
```

Summary of Control Structures
For controlling the flow of a program, the Java programming language has three loop
constructs, a flexible if-else statement, a switch statement, exception-handling statements, and branching statements.

3.4.1 Loops

Use the do-while statement to loop over a block of statements while a boolean expression remains true. The expression is evaluated at the bottom of the loop, so the statements within the do-while block execute at least once:

```
do {

statement (s)
} while (expression);
```

The for statement loops over a block of statements and includes an initialization expression, a termination condition expression, and an increment expression.

```
for (initialization ; termination ; increment) {
 statement (s)
        }
```

3.4.2 Decision-Making Statements

The Java programming language has two decision-making statements: if-else and switch. The more general-purpose statement is if; use switch to make multiple-choice decisions based on a single integer value. The following is the most basic if statement whose single statement block is executed if the boolean expression is true:

```
if (boolean expression)
{ statement (s)
        }
```

Here's an i f statement with a companion else statement. The i f statement executes the first block if the boolean expression is true; otherwise, it executes the second block:

```
if (boolean expression)
{ statement (s)
} else {
 statement (s)
        }
```

You can use e 1 s e i f_ to construct compound i f statements:

```
if (boolean expression) {
statement (s)
} else if (boolean expression) {
statement (s)
} else if (boolean expression) {
statement (s)
} else { statement (s)
```

The switch statement evaluates an integer expression and executes the appropriate case statement.

```
switch (integer expression) {
case integer expression:
statement (s)
break;
…
default:
          statement (s)
         break; }
```

4.0 CONCLUSION

The parts that form the basics in JAVA have been dealt with on completion of this unit. With the knowledge gained from unit I to unit 4, it is expected that you are able to write a JAVA code that will be object-based and perform the task it is given effectively. The remaining units combine what you have learnt so far with the power of object-oriented programming.

5.0 SUMMARY

An expression is a series of variables, operators, and method calls (constructed according to the syntax of the language) that evaluates to a single value. You can write compound expressions by combining expressions as long as the types required by all of the operators involved in the compound expression are correct. When writing compound expressions, you should be explicit and indicate with parentheses which operators should be evaluated first.

If you choose not to use parentheses, then the Java platform evaluates the compound expression in the order dictated by operator precedence. A statement forms a complete unit of execution and is terminated with a semicolon There are three kinds of statements: expression statements, declaration statements, and control structures. You can group zero or more statements together into a block with curly brackets ({ and }). Even though not required, we recommend using blocks with control structures even if there's only one statement in the block.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the data types of the following expressions, assuming that is type is int?
   a. i > 0
   b. i = 0
   c. i++
   d. (float) i
   e. i == 0
   f. "aString" + I

2. Consider the following expression: i--%5>0

a) What is the result of the expression, assuming that the value of i is initially 10?

b) Modify the expression so that it has the same result but is easier for programmers to read.

3. Look at the Sort Demo program. What control structures does it contain?

4. What's wrong with the following code snippet:

```
if (i = 1) {
/* do something */
}
```

5. Look at the While demo program and the DoWhileDemo program. What would the output be from each program if you changed the value of each program's

   copyFromMe string to golly gee. This is fun. Explain why you think each program will have the predicted output.

6. Consider the following code snippet.

```
if (aNumber >= 0)
 if (aNumber == 0)
System.out.println("first string");
else System.out.println("second string");
System.out.println("third string");
```

   a. What output do you think the code will produce if a Number is 3?
   b. Write a test program containing the code snippet; make a Number 3. What is the output of the program? Is it what you predicted? Explain why the output is what it is. In other words, what is the control flow for the code snippet?
   c. Using only spaces and line breaks, reformat the code snippet to make the control flow easier to understand.
   d. Use braces { and } to further clarify the code and reduce the possibility of errors in future.

7.0 REFERENCES/FURTHER READING

http://www.java.sun.com

MODULE 4 OBJECT-ORIENTED PROGRAMMING IN C++

UNIT 1 INTRODUCTION TO C++

CONTENTS

1.0 INTRODUCTION

More than any other programming language, C++ has become the most-widely used programming language. Its transitional ability from the more traditional concept to the object-oriented concept has helped to make it a language of choice for many.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- know the origin of C++
- differentiate between procedural and object-oriented programming in C++.
- Compile a C++ program
- execute/run a C++ compiled file

3.0 MAIN CONTENT

3.1 History of C++

3.1.1 How C++ Evolved

As object-oriented analysis, design, and programming began to catch on, Bjarne Stroustrup took the most popular language for commercial software development, C, and extended it to provide the features needed to facilitate object-oriented programming. He created C++, and in less than a decade it has gone from being used by only a handful of developers at AT&T to being the programming language of choice for an estimated one million developers worldwide. It is expected that by the end of the decade, C++ will be the predominant language for commercial software development.

While it is true that C++ is a superset of C, and that virtually any legal C program is a legal C++ program, the leap from C to C++ is very significant. C++ benefited from its relationship to C for many years, as C programmers could ease into their use of C++. To really get the full benefit of C++, however, many programmers found they had to unlearn much of what they knew and learn a whole new way of conceptualizing and solving programming problems.

3.1.2 The ANSI Standard

The idea of creating standards for C++ so that compiler developers will stick to a pattern of design evolved from the wide acceptance of the language and the rate at which different compilers took over the market. The Accredited Standards Committee, operating under the procedures of the American National Standards Institute (ANSI), is working to create an international standard for C++.

The ANSI standard is an attempt to ensure that C++ is portable--that code you write for Microsoft's compiler will compile without errors,

using a compiler from any other vendor. For most students of C++, the ANSI standard will be invisible. The standard has been stable for a while, and all the major manufacturers support the ANSI standard.

3.2 Programming Using C++

3.2.1 Preparing to Program

C++, perhaps more than other languages, demands that the programmer design the program before writing it. Trivial problems don't require much design, but students are advised to make it a habit to first design the programs before writing it. Complex problems, however, such as the ones professional programmers are challenged with every day, do require design, and the more thorough the design, the more likely it is that the program will solve the problems it is designed to solve, on time and on budget. A good design also makes for a program that is relatively bug-free and easy to maintain. It has been estimated that fully 90 percent of the cost of software is the combined cost of debugging and maintenance. To the extent that good design can reduce those costs, it can have a significant impact on the bottom-line cost of the project.

The first question you need to ask when preparing to design any program is, "What is the problem I'm trying to solve?" Every program should have a clear, well-articulated goal.

The second question every good programmer asks is, "Can this be accomplished without resorting to writing custom software?" Reusing an old program, using pen and paper, or buying software off the shelf is often a better solution to a problem than writing something new. The programmer who can offer these alternatives will never suffer from lack of work; finding less-expensive solutions to today's problems will always generate new opportunities later.

Assuming you understand the problem, and it requires writing a new program, you are ready to begin your design.

3.2.2 Development Environment

This course material makes the assumption that your computer has a mode in which you can write directly to the screen, without worrying about a graphical environment, such as the ones in Windows or on the Macintosh.

Your compiler may have its own built-in text editor, or you may be using a commercial text editor or word processor that can produce text files. The important thing is that whatever you write your program in, it

must save simple, plain-text files, with no word processing commands embedded in the text. Examples of safe editors include Windows Notepad, the DOS Edit command, Brief, Epsilon and EMACS. Many commercial word processors, such as WordPerfect, Microsoft Word, and dozens of others, also offer a method for saving simple text files.

The files you create with your editor are called source files, and for C++ they typically are named with the extension CPP, CP, or C. In this book, we'll name all the source code files with the CPP extension, but check your compiler for what it needs.

3.2.3 Procedural, Structured, and Object-Oriented Programming

Until recently, programs were thought of as a series of procedures that acted upon data. A procedure, or function, is a set of specific instructions executed one after the other. The data was quite separate from the procedures, and the trick in programming was to keep track of which functions called which other functions, and what data was changed. To make sense of this potentially confusing situation, structured programming was created.
The idea behind structured programming is as simple as the idea of divide and conquer. A computer program can be thought of as consisting of a set of tasks. Any task that is too complex to be described simply would be broken down into a set of smaller component tasks, until the tasks were sufficiently small and self-contained enough that they were easily understood.

As an example, computing the average salary of every employee of a company is a rather complex task. You can, however, break it down into these subtasks:

1. Find out what each person earns.
2. Count how many people you have.
3. Total all the salaries.
4. Divide the total by the number of people you have.

Totaling the salaries can be broken down into:

1. Get each employee's record.
2. Access the salary.
3. Add the salary to the running total.
4. Get the next employee's record.

In turn, obtaining each employee's record can be broken down into:

1. Open the file of employees.
2. Go to the correct record.
3. Read the data from disk.

Structured programming remains an enormously successful approach for dealing with complex problems. By the late 1980s, however, some of the deficiencies of structured programming had become all too clear.

First, it is natural to think of your data (employee records, for example) and what you can do with your data (sort, edit, and so on) as related ideas.

Second, programmers found themselves constantly reinventing new solutions to old problems. This is often called "reinventing the wheel," and is the opposite of reusability. The idea behind reusability is to build components that have known properties, and then be able to plug them into your program as you need them. Old-fashioned programs forced the user to proceed step-by-step through a series of screens. Modern event-driven programs present all the choices at once and respond to the user's actions.Object-oriented programming attempts to respond to these needs, providing techniques for managing enormous complexity, achieving reuse of software components, and coupling data with the tasks that manipulate that data.

The essence of object-oriented programming is to treat data and the procedures that act upon the data as a single "object"--a self-contained entity with an identity and certain characteristics of its own.

3.2.4 C++ and Object-Oriented Programming

C++ fully supports object-oriented programming, including the four pillars of object-oriented development: encapsulation, data hiding, inheritance, and polymorphism.

The property of being a self-contained unit is called encapsulation. With encapsulation, we can accomplish data hiding. Data hiding is the highly valued characteristic that an object can be used without the user knowing or caring how it works internally. Just as you can use a refrigerator without knowing how the compressor works, you can use a well-designed object without knowing about its internal data members.

C++ supports the properties of encapsulation and data hiding through the creation of user-defined types, called classes. Once created, a well-defined class acts as a fully encapsulated entity--it is used as a whole unit. The actual inner workings of the class should be hidden. Users of a

well-defined class do not need to know how the class works; they just need to know how to use it.

C++ supports the idea of reuse through inheritance. A new type, which is an extension of an existing type, can be declared. This new subclass is said to derive from the existing type and is sometimes called a derived type.

C++ supports the idea that different objects do "the right thing" through what is called function polymorphism and class polymorphism. Poly means many, and morph means form. Polymorphism refers to the same name taking many forms.
Exercise: What are the four pillars of object-oriented development
Answer: encapsulation, inheritance, data hiding, polymorphism

3.2.5 Compiling the Source Code

Although the source code is somewhat cryptic, and anyone who doesn't know C++ will struggle to understand what it is for, it is still in what is called human-readable form. The source code file is not yet a program, and it can't be executed, or run, as a program can.To turn source codes into programs, a compiler is used. How it is invoked differs from compiler to compiler.

After the source code is compiled, an object file is produced. This file is often named with the extension OBJ. This is still not an executable program, however. To turn this into an executable program, you must run the linker.

3.2.6 Creating an Executable File

C++ programs are typically created by linking together one or more OBJ files with one or more libraries. A library is a collection of linkable files that were supplied with your compiler, that you purchased separately, or that you created and compiled. All C++ compilers come with a library of useful functions (or procedures) and classes that you can include in your program. A function is a block of code that performs a service, such as adding two numbers or printing to the screen. A class is a collection of data and related functions.

The steps to create an executable file are

1. Create a source code file, with a CPP extension.
2. Compile the source code into a file with the OBJ extension.
3. Link your OBJ file with any needed libraries to produce an executable program.

3.1.7 The Development Cycle

If every program worked the first time they are tried, that would be the complete development cycle: Write the program, compile the source code, link the program, and run it. Unfortunately, almost every program, no matter how trivial, can and will have errors, or bugs, in the program. Some bugs will cause the compile to fail, some will cause the link to fail, and some will only show up when you run the program. Whatever type of bug you find, you must fix it, and that involves editing your source code, recompiling and relining, and then rerunning the program.

4.0 CONCLUSION

C++ is a landmark language in the programming world. It bridges the gap between its antecedents and successors in that it is procedural, structured and also object-oriented in nature. It serves as a good development tool to use for a wide range of applications from highly scientific to Marjory-database applications (in conjunction with databases). The advent of C++ has helped subsequent language (compiler) developers to focus more on the object-oriented technology and make a better world for programmers.

5.0 SUMMARY

In this unit, you have a good understanding of how C++ evolved and what problems it was designed to solve. You should feel confident that C++ provides the tools of object-oriented programming and the performance of a systems-level language, which makes C++ the development language of choice for many.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define Procedural Programming
2. What is a Structured Program
3. Differentiate between Procedural Programming and Object-Oriented Programming in C++
4. What are the steps necessary to make a C++ program executable

7.0 REFERENCES/FURTHER READING

Teach yourself C++ in 21 days, Greg Wiegand, http://www.mcp.com

Borland C++ Object-Oriented Programming.

UNIT 2 C++ LANGUAGE BASICS

CONTENTS

1.0 INTRODUCTION

Programs need a way to store the data they use. Variables and constants offer various ways to represent and manipulate that data.

In C++ a variable is a place to store information. A variable is a location in your computer's memory in which you can store a value and from which you can later retrieve that value.

2.0 OBJECTIVES

In this unit, you will learn:

- how to declare and define variables and constants
- how to assign values to variables and manipulate those values
- how to write the value of a variable to the screen.

3.0 MAIN CONTENT

3.1 Variables

Your computer's memory can be viewed as a series of cubbyholes. Each cubbyhole is one of many, many such holes all lined up. Each cubbyhole--or memory location--is numbered sequentially. These numbers are known as memory addresses. A variable reserves one or more cubbyholes in which you may store a value.

Your variable's name (for example, myVariable) is a label on one of these cubbyholes, so that you can find it easily without knowing its actual memory address. Depending on the size of my Variable, it can take up one or more memory addresses.

3.1.1 Setting Aside Memory

When you define a variable in C++, you must tell the compiler what kind of variable it is: an integer, a character, and so forth. This information tells the compiler how much room to set aside and what kind of value you want to store in your variable. Each cubbyhole is one byte large. If the type of variable you create is two bytes in size it needs two bytes of memory, or two cubbyholes. The type of the variable (for example, integer) tells the compiler how much memory (how many cubbyholes) to set aside for the variable.

Because computers use bits and bytes to represent values, and because memory is measured in bytes, it is important that you understand and are comfortable with these concepts.

3.1.2 Size of Integers

On any one computer, each variable type takes up a single, unchanging amount of room. That is, an integer might be two bytes on one machine, and four on another, but on either computer it is always the same, day in and day out.

A char variable (used to hold characters) is most often one byte long. A short integer is two bytes on most computers, a long integer is usually four bytes, and an integer (without the keyword short or long) can be two or four bytes. Listing 2.1 should help you determine the exact size of these types on your computer.

New Term: A character is a single letter, number, or symbol that takes up one byte of memory.

Listing 2.1. Determining the size oftypes on your computer.

```
l:  #include <iostream.h>
2:
3:  int main()
4:  {
5:  cout << "The size of an int is:\t\t"       << sizeof(int)    << "       bytes .\ n” ;
6:  cout << "The size of a short int is:\t" << sizeof(short)  << "       bytes .\ n” ;
7:  cout << "The size of a long int is:\t"   << sizeof(long)  <<  "       bytes .\ n” ;
8:  cout << "The size of a char is:\t\t"      << sizeof(char)  << "      bytes .\ n” ;
9:  cout << "The size of a float is:\t\t"     << sizeof(float) << "      bytes .\ n” ;
10: cout << "The size of a double is:\t"     << sizeof(double) << "          bytes .\
11:
12: return 0;
13: }
```

Output: The size of an int is: 2 bytes.
The size of a short int is: 2 bytes.
The size of a long int is: 4 bytes.
The size of a char is:1 bytes.
The size of a float is: 4 bytes.
The size of a double is: 8 bytes.

NOTE: On your computer, the number of bytes presented might be different.

Analysis: Most of Listing 2.1 should be pretty familiar. The one new feature is the use of the size of () function in lines 5 through 10. size of() is provided by your compiler, and it tells you the size of the object you pass in as a parameter. For example, on line 5 the keyword int is passed into size of(). Using size of(), I was able to determine that on my computer an int is equal to a short int which is 2 bytes.

3.1.3 Signed and Unsigned

In addition, all integer types come in two varieties: signed and unsigned. The idea here is that sometimes you need negative numbers, and sometimes you don't. Integers (short and long) without the word "unsigned" are assumed to be signed. Signed integers are either negative or positive. Unsigned integers are always positive.

Because you have the same number of bytes for both signed and unsigned integers, the largest number you can store in an unsigned integer is twice as big as the largest positive number you can store in a signed integer. An unsigned short integer can handle numbers from 0 to

65,535. Half the numbers represented by a signed short are negative, thus a signed short can only represent numbers from -32,768 to 32,767. If this is confusing, be sure to read Appendix A, "Operator Precedence."

3.1.4 Fundamental Variable Types

Several other variable types are built into C++. They can be conveniently divided into integer variables (the type discussed so far), floating-point variables, and character variables.

Floating-point variables have values that can be expressed as fractions--that is, they are real numbers. Character variables hold a single byte and are used for holding the 256 characters and symbols of the ASCII and extended ASCII character sets.

New Term: The ASCII character set is the set of characters standardized for use on computers. ASCII is an acronym for American Standard Code for Information Interchange. Nearly every computer operating system supports ASCII, though many support other international character sets as well.

The types of variables used in C++ programs are described in Table 2.1. This table shows the variable type, how much room this book assumes it takes in memory, and what kinds of values can be stored in these variables. The values that can be stored are determined by the size of the variable types, so check your output from Listing 2.1.

Table 2.1 Variable Types

Type	Size	Types
unsigned short int	2 bytes	0 to 65,535
short int	2 bytes	-32,768 to 32,767
unsigned long int	4 bytes	0 to 4,294,967,295
long int	4 bytes	-2,147,483,648 to 2,147,483,647
int (16 bit)	2 bytes	-32,768 to 32,767
int (32 bit)	4 bytes	-2,147,483,648 to 2,147,483,647
unsigned int (16 bit)	2 bytes	0 to 65,535
unsigned int (32 bit)	2 bytes	0 to 4,294,967,295
Char	1 byte	256 character values
Float	4 bytes	1.2e-38 to 3.4e38
Double	8 bytes	2.2e-308 to 1.8e308

NOTE:
The sizes of variables might be different from those shown in Table 2.1, depending on the compiler and the computer you are using. If your computer had the same output as was presented in Listing 2.1, Table 2.1 should apply to your compiler. If your output from Listing 2.1 was different, you should consult your compiler's manual for the values that your variable types can hold.

3.2 Defining a Variable

You create or define a variable by stating its type, followed by one or more spaces, followed by the variable name and a semicolon. The variable name can be virtually any combination of letters, but cannot contain spaces. Legal variable names include x, J22grsnf, and myAge. Good variable names tell you what the variables are for; using good names makes it easier to understand the flow of your program. The following statement defines an integer variable called myAge:

```
int myAge;
```

As a general programming practice, avoid such horrific names as J22grsnf, and restrict single-letter variable names (such as x or i) to variables that are used only very briefly. Try to use expressive names such as myAge or how Many. Such names are easier to understand three weeks later when you are scratching your head trying to figure out what you meant when you wrote that line of code.

Try this experiment: Guess what these pieces of programs do, based on the first few lines of code:
Example 1

```
 main()
{
unsigned short x;
unsigned short y;
ULONG z;
z = x * Y.
```

Example 2

```
main   ( )
{
unsigned short Width;
unsigned short Length;
unsigned short Area;
Area = Width * Length;
```

Clearly, the second program is easier to understand, and the inconvenience of having to type the longer variable names is more than made up for by how much easier it is to maintain the second program.

3.2.1 Case Sensitivity

C++ is case-sensitive. In other words, uppercase and lowercase letters are considered to be different. A variable named age is different from Age, which is different from AGE.

NOTE: Some compilers allow you to turn case sensitivity off. Don't be tempted to do this; your programs won't work with other compilers, and other C++ programmers will be very confused by your code.
There are various conventions for how to name variables, and although it doesn't much matter which method you adopt, it is important to be consistent throughout your program.

Many programmers prefer to use all lowercase letters for their variable names. If the name requires two words (for example, my car), there are two popular conventions: my_ car or myCar. The latter form is called camel-notation, because the capitalization looks something like a camel's hump.

Some people find the underscore character (my_ car) to be easier to read, while others prefer to avoid the underscore, because it is more difficult to type. This book uses camel-notation, in which the second and all subsequent words are capitalized: myCar, theQuickBrownFox, and so forth.
NOTE: Many advanced programmers employ a notation style that is often referred to as Hungarian notation. The idea behind Hungarian notation is to prefix every variable with a set of characters that describes its type. Integer variables might begin with a lowercase letter longs might begin with a lowercase I. Other notations indicate constants, global, pointers, and so forth. Most of this is much more important in C programming, because C++ supports the creation of user-defined types (see Day 6, "Basic Classes") and because C++ is strongly typed.

3.2.2 Keywords

Some words are reserved by C++, and you may not use them as variable names. These are keywords used by the compiler to control your program. Keywords include generally, any reasonable name for a variable is almost certainly not a keyword.
DO define a variable by writing the type, then the variable name**. DO** use meaningful variable names. **DO** remember that C++ is case sensitive. **DON'T** use C++ keywords as variable names**. DO** understand

the number of bytes each variable type consumes in memory, and what values can be stored in variables of that type. **DON'T** use unsigned variables for negative numbers.

Listing 2.2.A Demonstration Of The Use Of Variables.

```
1:  // Demonstration of variables
2:  #include <iostream.h>
3:
4:  int main()
5.  {
6:  unsigned short int Width = 5, Length;
7:  Length = 10;
8:
9:  // create an unsigned short and initialize with result
10: // of multiplying Width by Length
11: unsigned short int Area = Width * Length ;
12:
13: cout << "Width:" << Width << "\n";
14: cout << "Length: " <<  Length << endL;
15: cout << "Area: " << Area << endL
16: return 0;
17: }
```

Output: Width:5
Length: 10
Area: 50

Analysis: Line 2 includes the required include statement for the iostream's library so that cout will work. Line 4 begins the program.
On line 6, Width is defined as an unsigned short integer, and its value is initialized to 5. Another unsigned short integer, Length, is also defined, but it is not initialized. On line 7, the value 10 is assigned to Length.

On line 11, an unsigned short integer, Area, is defined, and it is initialized with the value obtained by multiplying Width times Length. On lines 13-15, the values of the variables are printed to the screen. Note that the special word end creates a new line.

3.2.3 Typedef

It can become tedious, repetitious, and, most important, error-prone to keep writing unsigned short int. C++ enables you to create an alias for this phrase by using the keyword typedef, which stands for type definition.

In effect, you are creating a synonym, and it is important to distinguish this from creating a new type (which you will do on Day 6). typedef is used by writing the keyword typedef, followed by the existing type and then the new name. For example

typedef unsigned short int USHORT

creates the new name USHORT that you can use anywhere you might have written unsigned short int.

Listing 2.3 is a replay of Listing 2.2, using the type definition USHORT rather than unsigned short int.

Listing 2.3. A demonstration of typedef.

```
2:  // Demonstrates typedef keyword
3:  #include <iostream.h>
4:
5:  typedef unsigned short int USHORT;
6:
7:  void main()
8.  {
9:  USHORT Width = 5;
10: USHORT Length;
11: Length = 10;
12: USHORT Area = Width *     Length ;
13: cout << "Width:" << Width << "\n";
14: cout << "Length: "  << Length << end1;
15: cout << "Area: " << Area << end1;
16: }
```

Output: Width:5
Length: 10
Area: 50

Analysis: On line 5, USHORT is type defined as a synonym for unsigned short int. The program is very much like Listing 2.2, and the output is the same.

3.2.4 Characters

Character variables (type char) are typically l byte, enough to hold 256 values (see Appendix C). A char can be interpreted as a small number (0-255) or as a member of the ASCII set. ASCII stands for the American standard code for information interchange. The ASC II character set its

ISO (International Standards Organization) equivalent are a way to encode all the letters, numerals, and punctuation marks.
Computer do not know about letters, punctuation, or sentences. All they understand are numbers. In fact, all they really know about is whether or not a sufficient amount of electricity is at a particular junction of wires. If so, it is represented internally as a 1; if not, it is represented as a 0. By grouping ones and zeros, the computer is able to generate patterns that can be interpreted as numbers, and these in turn can be assigned to letters and punctuation.

In the ASCII code, the lowercase letter "a" is assigned the value 97. All the lower- and uppercase letters, all the numerals, and all the punctuation marks are assigned values between I and 128. Another 128 marks and symbols are reserved for use by the computer maker, although the IBM extended character set has become something of a standard.

3.2.5 Characters and Numbers

When you put a character, for example, 'a', into a char variable, what is really there is just a number between 0 and 255. The compiler knows, however, how to translate back and forth between characters (represented by a single quotation mark and then a letter, numeral, or punctuation mark, followed by a closing single quotation mark) and one of the ASCII values.

The value/letter relationship is arbitrary; there is no particular reason that the lowercase "a" is assigned the value 97. As long as everyone (your keyboard, compiler, and screen) agrees, there is no problem. It is important to realize, however, that there is a big difference between the value 5 and the character '5'. The latter is actually valued at 53, much as the letter 'a' is valued at 97.

Listing 2.4. Printing characters based on numbers

```
1:      #include <iostream.h>
2:      int main()
3.      {
4:      for (int i = 32; i<128; i++)
5:      cout << (char) i;
6:      return 0;
7. }
```

```
Output:!"#$%G'()*+,./0123456789:;<>?@ABCDEFGHIJKLMNOP
QRSTUVWXYZ[\]^'abcdefghijklmnopgrstuvwxyz<I>-s
```

This simple program prints the character values for the integers 32 through 127.

3.2.6 Special Printing Characters

The C++ compiler recognizes some special characters for formatting. Table 2.2 shows the most common ones. You put these into your code by typing the backslash (called the escape character), followed by the character. Thus, to put a tab character into your code, you would enter a single quotation mark, the slash, the letter t, and then a closing single quotation mark:

```
char tabCharacter = '\t';
```

This example declares a char variable (tabCharacter) and initializes it with the character value \t, which is recognized as a tab. The special printing characters are used when printing either to the screen or to a file or other output device.

New Term: An escape character changes the meaning of the character that follows it. For example, normally the character n means the letter n, but when it is preceded by the escape character (\) it means new line.

Table 2.2. The Escape Characters.

Character	What it means
\n	new line
\t	Tab
\b	backspace
\"	double quote
\'	single quote
\?	question mark
\\	backslash

3.3 Constants

Like variables, constants are data storage locations. Unlike variables, and as the name implies, constants don't change. You must initialize a constant when you create it, and you cannot assign a new value later.

3.3.1 Literal Constants

C++ has two types of constants: literal and symbolic.
A literal constant is a value typed directly into your program wherever it is needed. For example

int myAge = 39;

myAge is a variable of type int; 39 is a literal constant. You can't assign a value to 39, and its value be changed.
can't

3.3.2 Symbolic Constants

A symbolic constant is a constant that is represented by a name, just as a variable is represented. Unlike a variable, however, after a constant is initialized, its value can't be changed.

If your program has one integer variable named students and other named classes, you could compute how many students you have, given a known number of classes, if you knew there were 15 students per class:

students = classes * 15;

In this example, 15 is a literal constant. Your code would be easier to read, and easier to maintain, if you substituted a symbolic constant for this value:
students = classes * studentsPerClass
If you later decided to change the number of students in each class, you could do so where you define the constant student per class without having to make a change every place you used that value.

There are two ways to declare a symbolic constant in C++. The old, traditional, now obsolete way is with a preprocessor directive, # define. To define a constant the traditional way, you would enter this:

#define studentsPerClass 15

Note that studentsPerClass is of no particular type (int, char, and so on). #define does a simple text substitution. Every time the preprocessor sees the word students PerClass, it puts in the text 15.
Because the preprocessor runs before the compiler, your compiler never sees your constant; it sees the number 15.

Although #define works, there is a new, much better way to define constants in C++:

const unsigned short int studentsPerClass = 15;

This example also declares a symbolic constant named studentsPerClass, but this time studentsPerClass is typed as an unsigned short int. This method has several advantages in making your code easier to maintain and in preventing bugs. The biggest difference is that this constant has a type, and the compiler can enforce that it is used according to its type.

NOTE: Constants cannot be changed while the program is running. If you need to change studentsPerClass, for example, you need to change the code and recompile.

DON'T us the term int. use short and long to make it clear which size number you intended. **DO** watch for numbers overrunning the size of the integer and wrapping around incorrect values. **DO** give your variables meaningful names that reflect their use. **DON'T** use keywords as variable names.

3.3.3 Enumerated Constants

Enumerated constants enable you to create new types and then to define variables of those types whose values are restricted to a set of possible values. For example, you can declare COLOR to be an enumeration, and you can define that there are five values for COLOR: RED, BLUE, GREEN, WHITE, and BLACK.

The syntax for enumerated constants is to write the keyword enum, followed by the type name, an open brace, each of the legal values separated by a cormna, and finally a closing brace and a semicolon. Here's an example:

enum COLOR {RED, BLUE, GREEN, WHITE, BLACK};

This statement performs two tasks:

1. It makes COLOR the name of an enumeration, that is, a new type.
2. It makes RED a symbolic constant with the value 0, BLUE a symbolic constant with the value l, GREEN a symbolic constant with the value 2, and so forth.

Every enumerated constant has an integer value. If you don't specify otherwise, the first constant will have the value 0, and the rest will count up from there. Any one of the constants can be initialized with a

particular value, however, and those that are not initialized will count upward from the ones before them. Thus, if you write

enum Color { RED=100, BLUE, GREEN=500, WHITE, BLACK=700};
then RED will have the value 100; BLUE, the value 101; GREEN, the value 500; WHITE, the value 501; and BLACK, the value 700.

You can define variables of type COLOR, but they can be assigned only one of the enumerated values (in this case, RED, BLUE, GREEN, WHITE, or BLACK, or else 100, 101, 500, 501, or 700). You can assign any color value to your COLOR variable. In fact, you can assign any integer value, even if it is not a legal color, although a good compiler will issue a warning if you do. It is important to realize that enumerator variables actually are of type unsigned int, and that the enumerated constants equate to integer variables. It is, however, very convenient to be able to name these values when working with colors, days of the week, or similar sets of values. Listing 2.5 presents a program that uses an enumerated type.

Listing 2.5. A demonstration of enumerated constants.

```
1: #include <iostream.h>
2: int main()
3. {
4:       enum Days { Sunday, Monday, Tuesday, Wednesday, Thursday,
Friday,          Saturday };
5:
6:       Days DayOff;
7:       int x;
8:
9:       Gout << "What day would you like off (0-6)? ";
         10:     cin >> x;
11:      DayOff = Days (x)
12:
13:      if (DayOff == Sunday 11 DayOff == Saturday)
14:      Gout << "\nYou're already off on weekends!\n";
15: else
16:      cout << "\nOkay, I'll put in the vacation day.\n";
17:      return 0;
18. }
```

Output: What day would you like off (0-6)? 1
Okay, I'll put in the vacation day.
What day would you like off (0-6)? 0
You're already off on weekends!

Analysis: On line 4, the enumerated constant DAYS is defined, with seven values counting upward from 0. The user is prompted for a day on line 9. The chosen value, a number between 0 and 6, is compared on line 13 to the enumerated values for Sunday and Saturday, and action is taken accordingly.
NOTE: For this and all the small programs in this book, I've left out all the code you would normally write to deal with what happens when the user types inappropriate data. For example, this program doesn't check, as it would in a real program, to make sure that the user types a number between 0 and 6. This detail has been left out to keep these programs small and simple, and to focus on the issue at hand.

4.0 CONCLUSION

Writing a C++ program needs a careful understudy of the rudiments of the project which should be designed beforehand to know the format the coding will take and the different variables that may be used. As a programmer, care should be taken to ensure the right variable type is used for efficient use of memory space.

5.0 SUMMARY

This chapter has discussed numeric and character variables and constants, which are either integral (char, short, and long int) or they are floating point (float and double). Numeric variables can also be signed or unsigned. Although all the types can be of various sizes among different computers, the type specifies an exact size on any given computer.

You must declare a variable before it can be used, and then you must store the type of data that you've declared as correct for that variable. If you put too large a number into an integral variable, it wraps around and produces an incorrect result.

This chapter also reviewed literal and symbolic constants, as well as remunerated constants, and showed two ways to declare a symbolic constant: using #define and using the keyword const.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the difference between an integral variable and a floating-point variable?
2. What are the differences between an unsigned short int and a long int?

3. What are the advantages of using a symbolic constant rather than a literal constant`?
4. What are the advantages of using the const keyword rather than # define ?
5. Given this enum, what is the value of BLUE?
   enum COLOR { WHITE, BLACK = 100, RED, BLUE, GREEN = 300 };
6. Which of the following variable names are good, which are bad, and which are invalid?
   a. Age
   b. !ex
   c. R791
   d. Total Income
   e. Invalid
7. What would be the correct variable type in which to store the following information?
   a. Your age.
   b. The area of your backyard.
   c. The number of stars in the galaxy.
   d. The average rainfall for the month of January.
8. Create good variable names for this information.
9. Declare a constant for pi as 3.14159.
10. Declare a float variable and initialize it using your pi constant.

7.0 REFERENCES/FURTHER READING

Teach yourself C++ in 21 days, Greg Wiegand, http://www.mcp.com

Borland C++ Object-Oriented Programming.

UNIT 3 C++ EXPRESSIONS AND STATEMENTS

CONTENTS

1.0 INTRODUCTION

At its heart, a program is a set of commands executed in sequence. The power in a program comes from its capability to execute one or another set of commands, based on whether a particular condition is true or false.

2.0 OBJECTIVES

At the end of this unit, you will be able to:

- define statements.
- define what blocks are.

- describe What expressions are.
- Know how to branch your code based on conditions.

3.0 MAIN CONTENT

3.1 Statements

In C++ a statement controls the sequence of execution, evaluates an expression, or does nothing (the null statement). All C++ statements end with a semicolon, even the null statement, which is just the semicolon and nothing else. One of the most common statements is the following assignment statement:

```
X = a + b;
```

Unlike in algebra, this statement does not mean that x equals a+b. This is read, "Assign the value of the sum of a and b to x," or "Assign to x, a+b." Even though this statement is doing two things, it is one statement and thus has one semicolon. The assignment operator assigns whatever is on the right side of the equal sign to whatever is on the left side.

3.1.1 Blocks and Compound Statements

Any place you can put a single statement, you can put a compound statement, also called a block. A block begins with an opening brace ({) and ends with a closing brace { I }. Although every statement in the block must end with a semicolon, the block itself does not end with a semicolon. For example

```
        {
temp = a;
a = b;
b = temp;
        }
```

This block of code acts as one statement and swaps the values in the variables a and b.

3.1.2 Expressions

Anything that evaluates to a value is an expression in C++. An expression . All said to return a value. Thus, 3 +2; returns the value 5 and so is an expression. expressions are statements.

Examples of valid expressions are given below:

```
3.2             // returns the value 3.2
PI              // float const that returns the value 3.14
```

SecondsPerMinute // int const that returns 60
constant equal to 60, all three of these statements are expressions.

A little complicated expression

```
x = a + b;
```

not only adds a and b and assigns the result to x, but returns the value of that assignment (the value of x) as well. Thus, this statement is also an expression. Because it is an expression, it can be on the right side of an assignment operator:

Listing 4.1. Evaluating complex expressions.

```
1:    #include <iostream.h>
2:    int main()
3. {
4:    int a=0, b=0, x=0, y=35;
5 :   cout << "a:    " << a << " b :        " << b;
6:    cout << " x: " << x << " y: " << y << endl;
7:    a = 9;
8:    b = 7;
9:    y = x = a+b;
10:   cout << "a: " << a << " b: " << b;
11:   cout << " x: " << x << " y: " << y << endl;
12:   return 0;
```

Copy and run the lines of code above.

3.2 Operators

An operator is a symbol that causes the compiler to take an action. Operators act on operands, and in C++ all operands are expressions. In C++ there are several different categories of operators. Two of these categories are

- Assignment operators.
- Mathematical operators.

3.2.1 Assignment Operators

The assignment operator (=) causes the operand on the left side of the assignment operator to have its value changed to the value on the right side of the assignment operator. The expression

```
x= a + b;
```

assigns the value that is the result of adding a and b to the operand x.

3.2.2 Mathematical Operators

There are five mathematical operators: addition (+), subtraction (-), multiplication (*), division (/), and modulus (%).

Addition and subtraction work as you would expect, although subtraction with unsigned integers can lead to surprising results, if the result is a negative number. You saw something much like this yesterday, when variable overflow was described. Listing 4.2 shows what happens when you subtract a large unsigned number from a small unsigned number.

Listing 4.2. A demonstration of subtraction and integer overflow.

```
1:      // Listing 4.2 - demonstrates subtraction and
2:      // integer overflow
3:      #include <# iostreamh>
4:
5:      int main()
 6: 1
7:      unsigned int difference;
8:      unsigned int bigNumber = 100;
9:      unsigned int smallNumber = 50;
10:     difference = bigNumber - smallNumber;
11:     cout << "Difference is: " << difference;
12:     difference = smallNumber - bigNumber;
13:     Gout << "\nNow difference is: " << difference <<endl;
14:     return 0;
15: }
```

Copy and run the lines of code above.

3.2.3 Integer Division and Modulus

Integer division is somewhat different from everyday division. When you divide 21 by 4, the result is a real number (a number with a fraction). Integers don't have fractions, and so the "remainder" is truncated. The answer is therefore 5. To get the remainder, you take 21 modulus 4 (21 % 4) and the result is 1. The modulus operator tells you the remainder after an integer division.

3.2.4 Increment and Decrement Operators

The most common value to add (or subtract) and then reassign into a variable is 1. In C++, increasing a value by I is called incrementing, and decreasing by I is called decrementing. There are special operators to perform these actions.

The increment operator (++) increases the value of the variable by 1, and the decrement operator (--) decreases it by 1. Thus, if you have a variable, C, and you want to increment it, you would use this statement:

C++; // Start with C and increment it. This statement is equivalent to the more verbose statement
C = C + 1;

which you learned is also equivalent to the moderately verbose statement

3.2.5 Prefix and Postfix

Both the increment operator (++) and the decrement operator(--) come in two varieties: prefix and postfix. The prefix variety is written before the variable name (++myAge); the postfix variety is written after (myAge++).

In a simple statement, it doesort much matter which you use, but in a complex statement when you have to assign the result to another variable, it matters very much. The prefix operator is evaluated before the assignment, the postfix is evaluated after.

The semantics of prefix is this: Increment the value and then fetch it. The semantics of postfix is different: Fetch the value and then increment the original.

This can be confusing at first, but if x is an integer whose value is 5 and you write int a = ++x;

you have told the compiler to increment x (making it 6) and then fetch that value and assign it to a. Thus, a is now 6 and x is now 6.

If, after doing this, you write
int b = x++;

you have now told the compiler to fetch the value in x (6) and assign it to b, and then go back and increment x. Thus, b is now 6, but x is now 7. Listing 4.3 shows the use and implications of both types.

Listing 4.3. A demonstration of prefix and postfix operators.

```
1: // Listing 4.3 - demonstrates use of
2: // prefix and postfix increment and
3: // decrement operators
```

```
4: #include <iostream.h>
5: int main()
6: {
 7:  int myAge = 39;           // initialize two integers

8:  int yourAge = 39;
9: cout << "I am: " myAge << " years old.\n";
10. cout << "You are: " // ++yourAge << yourAge << " years old\n";
11: myAge++;;                 // postfix increment
12:++Yurage'                          // prefix increment
13:      cout << "One year passes ...\n";
14:      cout << "I am: " << myAge << " years old.\n";
15:      cout << "You are: " << yourAge << " years old\n";
16:      cout << "Another year passes\n";
17:      cout << "I am: " << myAge++ << " years old.\n";
18:      cout << "You are: " << ++yourAge << " years old\n";
19:      cout << "Let's print it again.\n";
20:      cout << "I am: " << myAge << " years old.\n";
21:      cout << "You are: " << yourAge << " years old\n";
 22:     return 0;
23: }
```

Copy and run the lines of code above.

3.2.6 Operator Precedence

In the complex statement
x = 5 + 3 * 8;

which is performed first, the addition or the multiplication? If the addition is performed first, the answer is 8 * 8, or 64. If the multiplication is performed first, the answer is 5 + 24, or 29.

Every operator has a precedence value. Multiplication has higher precedence than addition, and thus the value of the expression is 29.
When two mathematical operators have the same precedence, they are performed in left-to-right order. Thus

x = 5 + 3 + 8 * 9 + 6 * 4;
is evaluated multiplication first, left to right. Thus, 8*9 = 72, and 6*4 = 24. Now the expression is essentially

= 5 + 3 + 72 + 24;
Now the addition, left to right, is 5 + 3 = 8; 8 + 72 = 80; 80 + 24 = 104.

Be careful with this. Some operators, such as assignment, are evaluated in right-to-left order! In any case, what if the precedence order doesn't meet your needs? Consider the expression

TotalSeconds = NumMinutesToThink + NumMinutesToType * 60

In this expression, you do not want to multiply the NumMinutesToType variable by 60 and then add it to NumMinutesToThink. You want to add the two variables to get the total number of minutes, and then you want to multiply that number by 60 to get the total seconds.
In this case, you use parentheses to change the precedence order. Items in parentheses are evaluated at a higher precedence than any of the mathematical operators. Thus
TotalSeconds = (NumMinutesToThink + NumMinutesToType) * 60 will accomplish what you want.

3.2.7 Relational Operators

The relational operators are used to determine whether two numbers are equal, or if one is greater or less than the other. Every relational statement evaluates to either 1 (TRUE) or 0 (FALSE). The relational operators are presented later.
If the integer variable myAge has the value 39, and the integer variable yourAge has the value 4 0, you can determine whether they are equal by using the relational "equals" operator:

myAge == yourAge; // is the value in myAge the same as in yourAge?

This expression evaluates to 0, or false, because the variables are not equal. The expression

myAge > yourAge; // is myAge greater than yourAge?
evaluates to 0 or false.

There are six relational operators: equals (==), less than (<), greater than (>), less than or equal to (<=), greater than or equal to (>=), and not equals (! =).

3.3 The if Statement

Normally, your program flows along line by line in the order in which it appears in your source code. The i f statement enables you to test for a condition (such as whether two variables are equal) and branch to different parts of your code, depending on the result.

The simplest form of an i f statement is this:

```
if (expression)
    statement;
```

The expression in the parentheses can be any expression at all, but it usually contains one of the relational expressions. If the expression has the value 0, it is considered false, and the statement is skipped. If it has any nonzero value, it is considered true, and the statement is executed. Consider the following example:

```
if (bigNumber > smallNumber)
    bigNumber = smallNumber;
```

This code compares bigNumber and smallNumber. If bigNumber is larger, the second line sets its value to the value of smallNumber.
Because a block of statements surrounded by braces is exactly equivalent to a single statement, the following type of branch can be quite large and powerful:

```
{(expression)
statement l;
statement 2;
statement 3;
}
```

Here's a simple example of this usage:

```
if (bigNumber > smallNumber)
{
bigNumber = smallNumber;
cout << "bigNumber: " << bigNumber << "\n";

cout << "smallNumber: " << smallNumber << "\n";
}
```

This time, if bigNumber is larger than smallNumber, not only is it set to the value of smallNumber, but an informational message is printed. Listing 4.4 shows a more detailed example of branching based on relational operators.

Listing 4.4. A demonstration of branching based on relational operators.

```
1: // Listing 4.4 - demonstrates if statement
2: // used with relational operators
3: #include <iostream.h>
4: int main()
5. {
6:       int RedSoxScore, YankeesScore;
7:       cout << "Enter the score for the Red Sox: ";
```

```
8:      cin >> RedSoxScore;
9:
10:     Cout << "\nEnter the score for the Yankees: ";
11:     cin >> YankeesScore;
12:
13:     Cout << "\n";
14:
15:     if (RedSoxScore > YankeesScore)
16:     Cout << "Go Sox!\n";
17:
18:     if (RedSoxScore < YankeesScore)
19:     {
20:     Cout << "Go Yankees!\n";
21:     cout << "Happy days in New York!\n";
 22:    }
23:
24:     if (RedSoxScore == YankeesScore)
25:     {
26:     cout << "A tie? Naah, can't be.\n";
27:     cout << "Give me the real score for the Yanks: ";
28:     cin >> YankeesScore;
29:
30:     if (RedSoxScore > YankeesScore)
31:     cout << "Knew it! Go Sox!";
32:
33:     if (YankeesScore > RedSoxScore)
34:     cout << "Knew it! Go Yanks!";
35:
36:     if (YankeesScore == RedSoxScore)
37:     cout << "Wow, it really was a tie!";
38:     }
39:
40:     cout << "\nThanks for telling me.\n";
41:     return 0;
42: }
```

In this example, getting a true result in one i f statement does not stop other if statements from being tested.

Copy and run the lines of code above.

3.3.1 If else

Often your program will want to take one branch if your condition is true, another if it is false. In Listing 4.3, you wanted to print one message (Go Sox!) if the first test (RedSoxScore >Yankees)

evaluated TRUE, and another message (Go Yanks !) if it evaluated FALSE.

The method shown so far, testing first one condition and then the other, works fine but is a bit cumbersome. The keyword else can make for far more readable code:

```
if (expression)
      statement;
else
         statement;
```

Listing 4.5 demonstrates the use of the keyword else

Listing 4.5. Demonstrating the else keyword.

```
1:  // Listing 4.5 - demonstrates if statement
2:  // with else clause
3:  #include <iostream.h>
4:  int main()
5:  {
6:  int firstNumber, secondNumber;
7:  cout << "Please enter a big number: ";

8:  cin >> firstNumber;
9:  cout << "\nPlease enter a smaller number: ";
10: cin >> secondNumber;
11: if (firstNumber > secondNumber)
12: cout << "\nThanks!\n";
13: else
14: cout << "\nOops. The second is bigger!";
15:
16: return 0;
17: }
```

Copy and run the lines of code above.

3.3.2 Advanced/Nested if Statements

it is worth noting that any statement can be used in an if or else clause, even another if or else statement. Thus, you might see complex if statement in the following form:

```
if (expression l)
if (expression2)
statement l;
else
```

```
if (expression3)

    statement2;
else
          statement3;
         }
       }
else
                statement4;
```

This cumbersome if statement says, "If expression I is true and expression2 is true, execute statement l. If expression is true but expression2 is not true, then if expression3 is true execute statement2. If expression is true but expression2 and expression3 are false, execute statement3. Finally, if expression is not true, execute statement4." As you can see, complex i f statements can be confusing!

Listing 4.6 gives an example of such a complex i f statement.

Listing 4.6. A complex, nested if statement.

```
1:      // Listing 4.5 - a complex needed
2:       // if statement
3: #include <iostream.h>
4: int main()
5. {
6:      // Ask for two numbers
7:      // Assign the numbers to bigNumber and  littleNumber,
8:      // If bigNumber is bigger than littleNumber,
9:      // see if they are evenly divisible
10:     // If they are, see if they are the same
11:
12:      int firstNumber , secondNumber ;
13:      Cout <, “ Enter two numbes . /nFirst : “;
14:     cin >> firstNumber;
 15:    Cout << “/nSecond: “;
16:     cin >> secondNumber;
17:     cout << “/n/n”;
18:
19:     if ( firstNumber >= secondNumber)
20:     {
{ 21:   if  ( first Number % secondNuber) = = 0) // evenly divisible?
22:     {
23:     if (firstNumber = = secondNumber )
24:     cout << "They are the same !\n”;
25:     else
26:     cout << "They  are not evently divisible!\n”;
27:     }
```

```
28:     else
29       cout << " They second one is larger!\n";

30:     }
31:     else
32:     cout << " Hey! The second one is larger !\n";
33:     return ) 0 ;
34: }
```

copy and run the lines of code above.

3.3.3 Using Braces in Nested if Statements

Although it is legal to leave out the braces on i f statements that are only a single statement, and it is legal to nest i f statements, such as

```
if (x > y)                  // if x is bigger than y
   if (x < z)    // and if x is smaller than z
                    x = y;          // then set x to the value in y
```

when writing large nested statements, this can cause enormous confusion. Remember, whitespace and indentation are a convenience for the programmer; they make no difference to the compiler. It is easy to confuse the logic and inadvertently assign an else statement to the wrong if statement. Listing 4.7 illustrates this problem.

Listing 4.7. A demonstration of why braces help clarify which else statement goes with which if statement.

```
1:    // Listing 4.7 - demonstrates why braces
2:    // are important in nested if statements
3:    #include <iostream.h>
4:    int main()
5:    {
6:    int x;
7:    cout << "Enter a number less than 10 or
8:    cin >> x;
9:    cout << "\n":
10:
11:   if (x > 10)
12:   if (x > 100)
13:   cout << "More than 100, Thanks!\n";
14:   else // not the else intended!
15:   cout << "Less than 10. Thanks!\n":
16:
17:   return 0;
18:   }
```

Copy and run the lines of code above.

Listing 4.8 fixes the problem by putting in the necessary braces.

Listing 4.8. A demonstration of the proper use of braces with an if statement

```
1:       //Listing 4.8 - demonstrates proper use of braces
2:       // in nested if statements
3:       #include <iostream.h>
4:       int main() 5.  {
6:       int x;
7:    cout << "Enter a number less than 10 or greater than 100: “;
8:                cin >> x;
9:       cout << "\n";
10:
11:      if (x > 10)
12:      {
13:      if (x > 100)
14:      cout << "More than 100, Thanks!\n";
15:      }
16:      Else              // not the else intended!
17:      cout << “ Less then 10, Thanks ! \ n”;
18:      return 0;
19:      }
```

copy and run the lines of code above.

3.4 Logical Operators

Often you want to ask more than one relational question at a time. "Is it true that x is greater than y, and also true that y is greater than z?" A program might need to determine that both of these conditions are true, or that some other condition is true, in order to take an action.

Imagine a sophisticated alarm system that has this logic: "If the door alarm sounds AND it is after six p.m. AND it is NOT a holiday, OR if it is a weekend, then call the police." C++'s three logical operators are used to make this kind of evaluation. These operators are listed in Table 3.1.

Table 3.1. The Logical Operators.

Operator	Symbol	Example
AND	& &	expression &&
OR	I I	expression II expression
NOT	!	! expression

3.4.1 Logical AND

A logical AND statement evaluates two expressions, and if both expressions are true, the logical AND statement is true as well. If it is true that you are hungry, AND it is true that you have money, THEN it is true that you can buy lunch. Thus,

if ((x == 5) && (y == 5))

would evaluate TRUE if both x and y are equal to 5, and it would evaluate FALSE if either one is not equal to 5. Note that both sides must be true for the entire expression to be true.
Note that the logical AND is two & & symbols. A single & symbol is a different operator.

3.4.2 Logical OR

A logical OR statement evaluates two expressions. If either one is true, the expression is true. If you have money OR you have a credit card, you can pay the bill. You don't need both money and a credit card; you need only one, although having both would be fine as well. Thus,

if ((x == 5) I I (y == 5))
evaluates TRUE if either x or y is equal to 5, or if both are.
Note that the logical OR is two I I symbols. A single I symbol is a different operator

3.4.3 Logical NOT

A logical NOT statement evaluates true if the expression being tested is false. Again, if the expression being tested is false, the value of the test is TRUE! Thus

if (! (x == 5))
is true only if x is not equal to 5. This is exactly the same as writing
if (x != 5)

3.4.4 Relational Precedence

Relational operators and logical operators, being C++ expressions, each precedence order (see Appendix A) that determines which relations are evaluated first. This fact is important when determining the value of the statement

if (x > 5 && y > 5 I I z > 5)

It might be that the programmer wanted this expression to evaluate TRUE if both x and y are greater than 5 or if z is greater than 5. On the other hand, the programmer might have wanted this expression to evaluate TRUE only if x is greater than 5 and if it is also true that either y is greater than 5 or z is greater than 5.

If x is 3, and y and z are both 10, the first interpretation will be true (z is greater than 5, so ignore x and y), but the second will be false (it isn't true that both x and y are greater than 5 nor is it true that z is greater than 5).
Although precedence will determine which relation is evaluated first, parentheses can both change the order and make the statement clearer:

```
if (      (x > 5)&& (y > 5 1 Iz > 5) )
```

Using the values from earlier, this statement is false. Because it is not true that x is greater than 5, the left side of the AND statement fails, and thus the entire statement is false. Remember that an AND statement requires that both sides be true--something isn't both "good tasting" AND "good for you" if it isn't good tasting.

NOTE: It is often a good idea to use extra parentheses to clarify what you want to group. Remember, the goal is to write programs that work and that are easy to read and understand.

3.4.5 Conditional (Ternary) Operator

The conditional operator (? :) is C++'s only ternary operator; that is, it is the only operator to take three terms.

The conditional operator takes three expressions and returns a value:
(expression l) ? (expression2) : (expression3)
This line is read as "If expression) is true, return the value of expression2; otherwise, return the value of expression3." Typically, this value would be assigned to a variable.

Listing 4.9 shows an i f statement rewritten using the conditional operator.

Listing 4.9. A demonstration of the conditional operator.

```
1:  // Listing 4.9 - demonstrates the conditional
2:  //
3:  #include <iostream.h>
4:  int main()
5:  {
6:  int x, y, z;
7:  cout << "Enter two numbers.\n":
```

```
8:    cout << "First: ";
9:    cin >> x;
10:   cout << "\nSecond: ":
11:   cin >> y;
12:   cout << "\n":
13:
14:   if (x > y)
15:   z = x ;
16:   else
17:   z = y ;
18:
19:   cout << "z: " < < z ;
20:   cout << "\n":
21:
22:   z = (x > y) ? x . y;
23:
24:   cout << "z: " < < z ;
25:   cout << "\n":
26:   return 0;
27:   }
```

Copy and run the lines of code above.

4.0 CONCLUSION

The composition of any program is made of the small bits of expressions and statements. Learning and understanding a programming language involve knowing the combination of these bits and pieces. Without them a programmer has not even started. They are the blood through which the other components of a program runs.

5.0 SUMMARY

This unit has covered a lot of material. You have learned what C++ statements and expressions are, what C++ operators do, and how C++ i f statements work.

You have seen that a block of statements enclosed by a pair of braces can be used anywhere a single statement can be used.

You have learned that every expression evaluates to a value, and that value can be tested in an if statement or by using the conditional operator. You've also seen how to evaluate multiple statements using the logical operator, how to compare values using the relational operators, and how to assign values using the assignment operator.

You have explored operator precedence. And you have seen how parentheses can be used to change the precedence and to make precedence explicit and thus easier to manage.

6.0 TUTOR-MARKED ASSIGNMENT

l. Why use unnecessary parentheses when precedence will determine which operators operators are acted on are acted on first ?
2. If the relational operators always return 1 or 0, why are other values considered true?
3. What effect do tabs, spaces, and new lines have on the program?
4. Are negative numbers true or false?

7.0 REFERENCES/FURTHER READING

Teach yourself C++ in 21 days, Greg Wiegand, http://www.mcp.com

Borland C++ Object-Oriented Programming.

UNIT 4 CLASSES I

CONTENTS

1.0 INTRODUCTION

Classes extend the built-in capabilities of C++ to assist you in representing and solving complex, real world problems. It is the beginning of the representation of the object-oriented programming in C++.
Object are simply instances of classes as variables are instances of primitive types.

2.0 OBJECTIVES

At the end of this unit, you will learn:

- what classes and objects are
- how to define a new class and create objects of that class
- what member functions and data members are
- what constructors are and how to use them.

3.0 MAIN CONTENT

3.1 Classes And Their Members

You make a new type by declaring a class. A class is just a collection of variables--often of different types--combined with a set of related functions.

One way to think about a car is as a collection of wheels, doors, seats, windows, and so forth. Another way is to think about what a car can do: It can move, speed up, slow down, stop, park, and so on. A class enables you to encapsulate, or bundle, these various parts and various functions into one collection, which is called an object.

Encapsulating everything you know about a car into one class has a number of advantages for a programmer. Everything is in one place, which makes it easy to refer to, copy, and manipulate the data. Likewise, clients of your class--that is, the parts of the program that use your class--can use your object without worry about what is in it or how it works.

A class can consist of any combination of the variable types and also other class types. The variables in the class are referred to as the member variables or data members. A Car class might have member variables representing the seats, radio type, tires, and so forth.

New Term: Member variables , also known as data members , are the variables in your class. Member variables are part of your class, just like the wheels and engine are part of your car.

The functions in the class typically manipulate the member variables. They are referred o as member functions or methods of the class. Methods of the Car class might include Start() and Brake(). A Cat class might have data members that represent age and weight; its methods might include Sleep(), Meow(), and Chase Mice().
New Term: Member functions , also known as methods , are the functions in your class. Member functions are as much a part of your class as the member variables. They determine what the objects of your class can do.

3.1.1 Declaring A Class

To declare a class, use the class keyword followed by an opening brace, and then list the data members and methods of that class. End the declaration with a closing brace and a semicolon. Here's the declaration of a class called Cat:

```
class Cat

unsigned int itsAge;
unsigned int its Weight;
Meow();
} ;
```

Declaring this class doesn't allocate memory for a Cat. It just tells the compiler what a Cat is, what data it contains (itsAge and its Weight), and what it can do (Meow()). It also tells the compiler how big a Cat is--that is, how much room the compiler must set aside for each Cat that you create. In this example, if an integer is two bytes, a Cat is only four bytes big: itsAge is two bytes, and its Weight is another two bytes. Meow() takes up no room, because no storage space is set aside for member functions (methods).

3.2 Declaring An Object

You define an object of your new type just as you define an integer variable:

```
unsigned int Gross Weight;// define an unsigned integer
Cat Frisky;    // define a Cat
```

This code defines a variable called Gross Weight whose type is an unsigned integer. It also defines Frisky, which is an object whose class (or type) is Cat.

3.3 Classes Versus Objects

You never pet the definition of a cat; you pet individual cats. You draw a distinction between the idea of a cat, and the particular cat that right now is shedding all over your living room. In the same way, C++ differentiates between the class Cat, which is the idea of a cat, and each individual Cat object. Thus, Frisky is an object of type Cat in the same way in which Gross Weight is a variable of type unsigned int.

New Term: An object is an individual instance of a class.

3.4 Accessing Class Members

Once you define an actual Cat object--for example, Frisky--you use the dot operator (.) to access the members of that object. Therefore, to assign 50 to Frisky's Weight member variable, you would write

```
Frisky. Weight = 50;
```

In the same way, to call the Meow() function, you would write Frisky. Meow();

When you use a class method, you call the method. In this example, you are calling Meow() on Frisky.

3.4.1 Assign to Objects, Not to Classes

In C++ you don't assign values to types; you assign values to variables. For example, you would never write

```
int = 5;                // wrong
```

The compiler would flag this as an error, because you can't assign 5 to an integer. Rather, you must define an integer variable and assign 5 to that variable. For example,

```
int x;          // define x to be an int
x = 5;          // set x's value to 5
```

This is a shorthand way of saying, "Assign 5 to the variable x, which is of type int." In the same way, you wouldn't write

```
Cat.age=5;    // wrong
```

The compiler would flag this as an error, because you can't assign 5 to the age part of a Cat. Rather, you must define a Cat object and assign 5 to that object. For example,

```
Cat Frisky;           // just like int x;
Frisky.age = 5;       // just like x = 5;
```

3.4.2 If You Don’t Declare It, Your Class Wont Have It

Try this experiment: Walk up to a three-year-old and show her a cat. Then say, "This is Frisky. Frisky knows a trick. Frisky, bark." The child will giggle and say, "No, silly, cats can't bark."

If you wrote

```
Cat Frisky;           // make a Cat named Frisky
Frisky. Bark()              // tell Frisky to bark
```

the compiler would say, No, silly, Cats can't bark. (Your compiler's wording may vary). The compiler knows that Frisky can't bark because the Cat class doesn't have a Bark() function. The compiler wouldn't even let Frisky meow if you didn't define a Meow() function.

3.5 Access Modifiers

There are three keywords in C++ that determine the level of access the users will have on objects. The declaration of these must be done at class declaration level. They are private, public and protected. We shall discuss private and public in this unit and leave protected for the next.

3.5.1 Private Versus Public

Other keywords are used in the declaration of a class. Two of the most important are public and private.

All members of a class--data and methods--are private by default. Private members can be accessed only within methods of the class itself. Public members can be accessed through any object of the class. This distinction is both important and confusing. To make it a bit clearer, consider an example from earlier in this unit:

```
class Cat
        {
unsigned int itsAge;
unsigned int itsWeight;
Meow ();
};
```

In this declaration, itsAge, its Weight, and Meow() are all private, because all members of a class are private by default. This means that unless you specify otherwise, they are private.

However, if you write

```
Cat Boots;
Boots.itsAge=5;       // error! can't access private data!
```

the compiler flags this as an error. In effect, you've said to the compiler, "I'll access itsAge, itsWeight, and Meow() only from within member functions of the Cat class." Yet here you've accessed the itsAge member variable of the Boots object from outside a Cat method. Just because Boots is an object of class Cat, that doesn't mean that you can access the parts of Boots that are private.

This is a source of endless confusion to new C++ programmers. Why can't Boots access his own age?" The answer is that Boots can, but you can't. Boots, in his own methods, can access all his parts--public and private. Even though you've created a Cat, that doesn't mean that you can see or change the parts of it that are private.

The way to use Cat so that you can access the data members is

```
class Cat
public:
unsigned int itsAge;
unsigned int its Weight;
Meow ();
```

```
};
```
Now itsAge, itsWeight, and Meow() are all public. Boots.itsAge=5 compiles without problems.

Listing 6.1 shows the declaration of a Cat class with public member variables.

Listing 6.1. Accessing the public members of a simple class.

```
1:    // Demonstrates declaration of a class and
2:    // definition of an object of the class,
 3:
4:    #include <overstream.h>    // for court
5:
6:    class Cat       // declare the class object
7. {
8:    public:         // members which follow are public
9:    int itsAge;
10:   int itsWeight; 11. };
12:
13:
14:   void main()
15:   {
16:   Cat Frisky;
17:   Frisky.itsAge = 5;    // assign to the member variable
18:   cout << "Frisky is a cat who is " ;
19:   cout << Frisky.itsAge << " years old.\n";
20:
```

Output: Frisky is a cat who is 5 years old.

Analysis: Line 6 contains the keyword class. This tells the compiler that what follows is a declaration. The name of the new class comes after the keyword class. In this case, it is Cat. The body of the declaration begins with the opening brace in line 7 and ends with a closing brace and a semicolon in line 11. Line 8 contains the keyword public, which indicates that everything that follows is public until the keyword private or the end of the class declaration.

Lines 9 and 10 contain the declarations of the class members itsAge and its Weight

.

Line 14 begins the main function of the program. Frisky is defined in line 16 as an instance of a Cat--that is, as a Cat object. Frisky's age is set in line 17 to 5. In lines 18 and 19, the itsAge member variable is used to print out a message about Frisky.

NOTE: Try commenting out line 8 and try to recompile. You will receive an error on line 17 because itsAge will no longer have public access. The default for classes is private access.

3.5.2 Make data members private

As a general rule of design, you should keep the data members of a class private. Therefore, you must create public functions known as accessor/mutator methods to set and get the private member variables.

These accessor/mutator methods are the member functions that other parts of your program call to get and set your private member variables.

New Term: A public accessor/gettor method is a class member function used either to read the value of a private class member variable while a mutator / settor method is used to set its value. Why bother with this extra level of indirect access? After all, it is simpler and easier to use the data, instead of working through accessor/mutator functions. Accessor/mutator functions enable you to separate the details of how the data is stored from how it is used. This enables you to change how the data is stored without having to rewrite functions that use the data.

If a function that needs to know a Cat's age accesses itsAge directly, that function would need to be rewritten if you, as the author of the Cat class, decided to change how that data is stored. By having the function call GetAge(), your Cat class can easily return the right value no matter how you arrive at the age. The calling function doesn't need to know whether you are storing it as an unsigned integer or a long, or whether you are computing it as needed.

This technique makes your program easier to maintain. It gives your code a longer life because design changes don't make your program obsolete. Listing 6.2 shown the cat class modified to include private data members and public accessor/mutator methods. Note that this is not an executable listing.

Listing 6.2. A class with accessor/mutator methods.

```
1:      // Cat class declaration
2:      // Data members are private, public accessor/mutator methods
3:      // mediate setting and getting the values of the private data
4:
5:      class Cat
6.      {
7:       public:
8:      // public accessor/mutators
9:      unsigned int GetAge();
```

```
10:     void SetAge(unsigned int Age);
11:
12:     unsigned int GetWeight();
13:     void SetWeight(unsigned int Weight);
14:
15:     // public member functions
16. Meow();
17:
18:     // private data members
9: private:
20:     unsigned int itsAge;
21:     unsigned int itsWeight;
22:
23. };
```

Analysis: This class has five public methods. Lines 9 and 10 contain the accessor/mutator methods for itsAge. Lines 12 and 13 contain the accessor/mutator methods for its Weight. These accessor/mutator functions set the member variables and return their values.

The public member function Meow() is declared in line 16. Meow() is not an accessor/mutator function. It doesn't get or set a member variable; it performs another service for the class, printing the word Meow.

The member variables themselves are declared in lines 20 and 21.

To set Frisky's age, you would pass the value to the SetAge() method, as in Cat Frisky;
Frisky.SetAge(5);// set Frisky's age using the public accessor/mutator

3.5.3 Privacy Versus Security

Declaring methods or data private enables the compiler to find programming mistakes before they become bugs. Any programmer worth his consulting fees can find a way around privacy if he wants to. Stroustrup, the inventor of C++, said, "The C++ access control mechanisms provide protection against accident--not against fraud." (ARM, 1990.)

DO declare member variables private. **DO** use public accessor/mutator methods. **DON'T** try to use private member variables from outside the class. **DO** access private member variables from within class member functions.

3.6 Implementing Class Methods

As you've seen, an accessor/mutator function provides a public interface to the private data members of the class. Each accessor/mutator function, along with any other class methods that you declare, must have an implementation. The implementation is called the function definition.

A member function definition begins with the name of the class, followed by two colons, the name of the function, and its parameters. Listing 6.3 shows the complete declaration of a simple Cat class and the implementation of its accessor/mutator function and one general class member function.

Listing 6.3. Implementing the methods of a simple class.

```
1:    // Demonstrates declaration of a class and
2:    // definition of class methods,
3:
4:    #include <iostream.h> // for cout
5:
6:    class Cat // begin declaration of the class
7:    {
8:    public: // begin public section
9:    int GetAge(); // accessor/mutator function
10:   void SetAge (int age); // accessor/mutator function
11:   void Meow(); // general function
12:   private: // begin private section
13:   int itsAge; // member variable
14:   };
15:
16:   // GetAge, Public accessor/mutator function
17:   // returns value of itsAge member
18:   int Cat::GetAge()
19:   {
20:   return itsAge;
21:   }
22:
23:   // definition of SetAge, public
24:   // accessor/mutator function
25:   // returns sets itsAge member
26:   void Cat::SetAge(int age)
27:   {
28:   // set member variable its age to
29:   // value passed in by parameter age
30:   itsAge = age ;
31:   }
32:
33:   // definition of Meow method
34:   // returns: void
35:   // parameters: None
36:   // action: Prints "meow" to screen
```

```
37:    void Cat::Meow()
38:    {
39:    cout << "Meow.\n";
40:    }
41:
42:    // create a cat, set its age, have it
43:    // meow, tell us its age, then meow again.
44:    int main()
45:
46.    Cat Frisky;
47:    Frisky.SetAge(5);
48.    Frisky.Meow();
49:    cout << "Frisky is a cat who is  " :
50:    cout << Frisky.GetAge() << " year old .\n";
51:    Frisky.Meow();
52;    return 0;
53:    }
```

Output: Meow.
Frisky is a cat who is 5 years old.

Meow.

Analysis: Lines 6-14 contain the definition of the Cat class. Line 8 contains the keyword public, which tells the compiler that what follows is a set of public members. Line 9 has the declaration of the public accessor/mutator method GetAge(). GetAge() provides access to the private member variable itsAge, which is declared in line 13. Line 10 has the public accessor/mutator function SetAgeQ. SetAge() takes an integer as an argument and sets itsAge to the value of that argument. Line 11 has the declaration of the class method Meow(). Meow() is not an accessor/mutator function. Here it is a general method that prints the word Meow to the screen.

Line12 begins the private section, which includes declaration in line 13 of the private member variable itsAge. The class declaration ends with a closing brace and semicolon in line 14.

Lines 18-21 contain the definition of the member function GetAge(). This method takes no parameters; it returns an integer. Note that class methods include the class name followed by two colons and the function name (Line 18). This syntax tells the compiler that the GetAge() function that you are defining here is the one that you declared in the Cat class. With the exception of this header line, the GetAge ( ) function is created like any other function.

The GetAge() function takes only one line; it returns the value in itsAge. Note that the main() function cannot access itsAge because itsAge is private to the Cat class. The main() function has access to the public method GetAge(). Because GetAge() is a member function of the Cat

class, it has full access to the itsAge variable. This access enables GetAge() to return the value of itsAge to main().

Line 26 contains the definition of the SetAge ( ) member function. It takes an integer parameter and sets the value of itsAge to the value of that parameter in line 30. Because it is a member of the Cat class, SetAge() has direct access to the member variable itsAge.
Line 37 begins the definition, or implementation, of the Meow() method of the Cat class. It is a one-line function that prints the word Meow to the screen, followed by a new line. Remember that the \n character prints a new line to the screen.

Line 44 begins the body of the program with the familiar main() function. In this case, it takes no arguments and returns void. In line 46, main() declares a Cat named Frisky. In line 47, the value 5 is assigned to the itsAge member variable by way of the SetAge() accessor/mutator method. Note that the method is called by using the class name (Frisky) followed by the member operator (.) and the method name (SetAge()). In this same way, you can call any of the other methods in a class.

Line 48 calls the Meow() member function, and line 49 prints a message using the GetAge() accessor/mutator. Line 51 calls Meow() again.

4.0 CONCLUSION

Classes are gateway to object-oriented programming in C++. The much desired technology is made available through the use of classes. It extends the privilege of creating own types, as the primitive types are created by compiler developers, that suit the development by programmers, make them more in control and make their jobs much easier to accomplish.

5.0 SUMMARY

In this unit, you learned how to create new data types called classes. You learned how to define variables of these new types, which are called objects.

A class has data members, which are variables of various types, including other classes. A class also includes member functions--also known as methods. You use these member functions to manipulate the data members and to perform other services.

Class members, both data and functions, can be public or private. Public members are accessible to any part of your program. Private members are accessible only to the member functions of the class.

6.0 TUTOR-MARKED ASSIGNMENT

1. How big is a class object?
2. If I declare a class Cat with a private member itsAge and then define two Cat objects, Frisky and Boots, can Boots access Frisky's itsAge member variable?
3. Why shouldn't I make all the data members public?
4. If using a const function to change the class causes a compiler error, why shouldn't I just leave out the word const and be sure to avoid errors?
5. Is there ever a reason to use a structure in a C++ program?
6. What is the dot operator, and what is it used for?
7. Which sets aside memory - class declaration or definition?
8. Is the declaration of a class its interface or its implementation?
9. What is the difference between public and private data members?
10. Can member functions be private?
11. Can data members be public?
12. Can two objects of the same class have different values in their data members?
13. Do class declarations end with a semicolon? Do class method definitions?

7.0 REFERENCES/FURTHER READING

Teach yourself C++ in 21 days, Greg Wiegand, http://www.mcp.com

Borland C++ Object-Oriented Programming.

UNIT 5 CLASSES II

CONTENTS

1.0 INTRODUCTION

The idea of using classes is good, but if it does not give the flexibility and ease of use of the primitive types, the aim of its object-oriented nature will be defeated. Programs will still be as complex as ever and compiler developers will have created another problem while erasing one. The use of constructors and destructors helps a lot in doing away with this development. This unit talks about how the C++ programmer can use the constructor and destructor technology and achieve fantastic result.

2.0 OBJECTIVES

At the end of this unit, you should know:

- what constructors and destructors are
- how to declare constructors and destructors
- how to access object variables without changing them
- what inline implementation is.

3.0 MAIN CONTENT

3.1 Constructors and Destructors

Constructors and destructors are simply functions, although special ones, in C++. A constructor is used in classes to initialize variables and create memory spaces. A destructor, on the other hand, is used to free memory spaces. We shall use the knowledge of primitive types to explain them.

There are two ways to define an integer variable. You can define the variable and then assign a value to it later in the program. For example,

```
int Weight;          // define a variable
Weight = 7;          // assign it a value
```

Or you can define the integer and immediately initialize it. For example,

```
int Weight = 7;      // define and initialize to 7
```

Initialization combines the definition of the variable with its initial assignment. Nothing stops you from changing that value later. Initialization ensures that your variable is never without a meaningful value.

How do you initialize the member data of a class? Classes have a special member function called a constructor. The constructor can take parameters as needed, but it cannot have a return value--not even void. The constructor is a class method with the same name as the class itself.
Whenever you declare a constructor, you'll also want to declare a destructor. Just as constructors create and initialize objects of your class, destructors clean up after your object and free any mernory you might have allocated. A destructor always has the name of the class, preceded by a tilde (~). Destructors take no arguments and have no return value. Therefore, the Cat declaration includes

```
~Cat ( ) ;
```

3.1.1 Default Constructors and Destructors

If you don't declare a constructor or a destructor, the compiler makes one for you. The default constructor and destructor take no arguments and do nothing.

What good is a constructor that does nothing? In part, it is a matter of form. All objects must be constructed and destructed, and these do-nothing functions are called at the right time. However, to declare an object without passing in parameters, such as

Cat Rags; // Rags gets no parameters you must have a constructor in the form
Cat ( ) ;

When you define an object of a class, the constructor is called. If the Cat constructor took two parameters, you might define a Cat object by writing
Cat Frisky (5,7);

If the constructor took one parameter, you would write
Cat Frisky (3);
In the event that the constructor takes no parameters at all, you leave off the parentheses and write
Cat Frisky ;
This is an exception to the rule that states all functions require parentheses, even if they take no parameters. This is why you are able to write
Cat Frisky;

Which is a call to the default constructor. It provides no parameters, and it leaves off the parentheses. You don't have to use the compiler-provided default constructor. You are always free to write your own constructor with no parameters. Even constructors with no parameters can have a function body in which they initialize their objects or do other work.

As a matter of form, if you declare a constructor, be sure to declare a destructor, even if your destructor does nothing. Although it is true that the default destructor would work correctly, it doesn't hurt to declare your own. It makes your code clearer.

Listing 5.1 rewrites the Cat class to use a constructor to initialize the Cat object, setting its age to whatever initial age you provide, and it demonstrates where the destructor is called.

Listing 5.1 Using constructors and destructors.
```
1:    // Demonstrates declaration of a constructors and
2:    // destructor for the Cat class
3:
4:    #include <iostream.h>        // for cout
5:
6:    class Cat       // begin declaration of the class
 7. {
8:    public:         // begin public section
9:    Cat(int initialAge);   // constructor
10:   ~Cat();         // destructor
```

```
11:     int GetAge(); // accessor/mutator functicn
12:     void SetAge(int age);         // accessor/mutator function
13:     void Meow();
14:     private:         // begin private section
15:     int itsAge;     // member variable
16. };
17:
18: // constructor of Cat,
19: Cat::Cat(int initialAge)
20: 1
21:     itsAge = initialAge;
22: }
23:
24: Cat::~Cat()// destructor, takes no action
25:  {                                    // destructor, takes no action
26: }
 27:
28: // GetAge, Public accessor/mutator function
29: // returns value of itsAge member
30: {   int Cat::GetAge()
31: {
32:     return itsAge;
33:     }
34:
35:      // Definition of SetAge, public
36:     // accessor/mutator function
37:
38:     void Cat::SetAge(int age)
39:     {
40:     // set member variable its age to
41:     // value passed in by parameter age
42:     itsAge = age;
43:     }
44:
45:     // definition of Meow method
46:     // returns: void
47:     // parameters: None
48:     // action: Prints "meow" to screen
49:     void Cat::Meow()
50:     {
51:     cout << "Meow.\n";
52: 1
53:
54:     // create a cat, set its age, have it
55      // meow, tell us its age, then meow again.
56      56: int main()
```

```
57:      {
58:     Cat Frisky(5);
59       Frisky.Meow();
60:     cout << "Frisky is a cat who is " ;
61:     cout << Frisky.GetAge() << " years old.\n";
62:     Frisky.Meow();
63:     Frisky.SetAge(7);
64:     cout << "Now Frisky is " ;
65:     cout << Frisky.GetAge() << " years old.\n";
66;     return 0;
67: }
```

Output: Meow.
Frisky is a cat who is 5 years old. Meow.
Now Frisky is 7 years old.

Analysis: Line 9 adds a constructor that takes an integer. Line 10 declares the destructor, which takes no parameters. Destructors never take parameters, and neither constructors nor destructors return a value--not even void.

Lines 19-22 show the implementation of the constructor. It is similar to the implementation of the SetAge() accessor/mutator function. There is no return value.
Lines 24-26 show the implementation of the destructor ~Cat(). This function does nothing, but you must include the definition of the function if you declare it in the class declaration.

Line 58 contains the definition of a Cat object, Frisky. The value 5 is passed in to Frisky's constructor. There is no need to call SetAge(), because Frisky was created with the value 5 in its member variable itsAge, as shown in line 61. In line 63, Frisky's itsAge variable is reassigned to 7. Line 65 prints the new value.
DO use constructors to initialize your objects. DON'T give constructors or destructors a return value. DON'T give destructors parameters.

3.1.2 Constant Member Functions

If you declare a class method coast, you are promising that the method won't change the value of any of the members of the class. To declare a class method constant, put the keyword coast after the parentheses but before the semicolon. The declaration of the constant member function SomeFunction() takes no arguments and returns void. It looks like this:

```
void SomeFunction() const;
```

Accessor/mutator functions are often declared as constant functions by using the const modifier. The Cat class has two accessor/mutator functions:

void SetAge(int anAge);
int GetAge () ;

SetAgeQ cannot be coast because it changes the member variable itsAge. GetAge(), on the other hand, can and should be coast because it doesn't change the class at all. GetAge() simply returns the current value of the member variable itsAge. Therefore, the declaration of these functions should be written like this:

void SetAge(int anAge);

int GetAge () coast;
If you declare a function to be const, and the implementation of that function changes the object by changing the value of any of its members, the compiler flags it as an error. For example, if you wrote GetAge() in such a way that it kept count of the number of times that the Cat was asked its age, it would generate a compiler error. This is because you would be changing the Cat object by calling this method.

NOTE: Use const whenever possible. Declare member functions to be const whenever they should not change the object. This lets the compiler help you find errors; it's faster and less expensive than doing it yourself.
it is good programming practice to declare as many methods to be const as possible. Each time you do, you enable the compiler to catch your errors, instead of letting your errors become bugs that will show up when your program is running.

3.1.3 Interface Versus Implementation

As you've learned, clients are the parts of the program that create and use objects of your class. You can think of the interface to your class--the class declaration--as a contract with these clients. The contract tells what data your class has available and how your class will behave.

For example, in the Cat class declaration, you create a contract that every Cat will have a member variable itsAge that can be initialized in its constructor, assigned to by its SetAge() accessor/mutator function, and read by its GetAge() accessor/mutator. You also promise that every Cat will know how to Meow(). If you make GetAge() a const function--as you should--the contract also promises that GetAge() won't change the Cat on which it is called.

C++ is strongly typed, which means that the compiler enforces these contracts by giving you a compiler error when you violate them. Listing 5.2 demonstrates a program that doesn't compile because of violations of these contracts.

WARNING: Listing 5.2 does not compile!

Listing 5.2. A demonstration of violations of the interface.

```
1:      // Demonstrates compiler errors
2:
3:
4:      #include <iostream.h >// for Gout
5:
6:      class Cat
7:      {
8:      public:
9:      Cat(int initialAge);
10:     ~Cat();
11:     int GetAge() const;   // const accessor/mutator function
12:     void SetAge (int age);
13:     void Meow();
14:     private:
15:     int itsAge;
16: };
17:
18:     // constructor of Cat,
19:     Cat::Cat(int initialAge)
20:     {
21:     itsAge = initialAge;
21:     cout << "Cat Constructor\n";
22:     }
23:
24:     Cat::-Cat()     // destructor, takes no action
25:     {
26:     cout << " cat  Destructor \n";
27:     }
28:     // GetAge, const function
29:     // but we violate const !
30:     int cat:: GetAge ( ) const
31:     {
32:
33:     }
34:
35:     // definition of SetAge, public
36:     // accessor/mutator function
```

```
37:
38:     void Cat::SetAge(int age)
39:     {
40:     // set member variable its age to
41:     // value passed in by parameter age
42:     itsAge = age;
43:     }
44:
45:     // definition of Meow method
46:     // returns: void
47:     // parameters: None
48:      // action: Prints "meow" to screen
49:     void Cat::Meow()
50:     {
51:     cout << "Meow.\n";
52:     }
53:
54:     // demonstrate various violations of the
55      // interface, and resulting compiler errors
56      int main()
57:      {
58:     Cat Frisky;    // doesn't match declaration
59:     Frisky.Meow();
60:     61:Frisky.itsAge = 7;          // itsAge is private
61:
62:
63  }
```

Analysis: As it is written, this program doesn't compile. Therefore, there is no output. This program was fun to write because there are so many errors in it.
Line 11 declares GetAge() to be a const accessor/mutator function--as it should be. In the body of GetAge(), however, in line 32, the member variable itsAge is incremented. Because this method is declared to be const, it must not change the value of itsAge. Therefore, it is flagged as an error when the program is compiled..

In line 13, Meow() is not declared const. Although this is not an error, it is bad programming practice. A better design takes into account that this method doesn't change the member variables of Cat. Therefore, Meow() should be const.

Line 58 shows the definition of a Cat object, Frisky. Cats now have a constructor, which takes an integer as a parameter. This means that you must pass in a parameter. Because there is no parameter in line 58, it is flagged as an error.

Line 60 shows a call to a class method, Bark(). Bark() was never declared. Therefore, it is illegal.
Line 61 shows itsAge being assigned the value 7. Because itsAge is a private data member, it is flagged as an error when the program is compiled.

3.1.4 Where to Put Class Declarations and Method Definitions

Each function that you declare for your class must have a definition. The definition is also called the function implementation. Like other functions, the definition of a class method has a function header and a function body. The definition must be in a file that the compiler can find. Most C++ compilers want that file to end with .C or.CPP.

NOTE: Many compilers assume that files ending with C are C programs, and that C++ program files end with CPP. You can use any extension, but CPP will minimize confusion.

You are free to put the declaration in this file as well, but that is not good programming practice. The convention that most programmers adopt is to put the declaration into what is called a header file, usually with the same name but ending in H, HP, or HPP. This book names the header files with HPP, but check your compiler to see what it prefers.

For example, you put the declaration of the Cat class into a file named CAT.HPP, and you put the definition of the class methods into a file called CAT.CPP. You then attach the header file to the CPP file by putting the following code at the top of CAT.CPP:

#include Cat.hpp

This tells the compiler to read CAT.HPP into the file, just as if you had typed in its contents at this point. Why bother separating them if you're just going to read them back in? Most of the time, clients of your class don't care about the implementation specifics. Reading the header file tells them everything they need to know; they can ignore the implementation files.

NOTE: The declaration of a class tells the compiler what the class is, what data it holds, and what functions it has. The declaration of the class is called its interface because it tells the user how to interact with the class. The interface is usually stored in an HPP file, which is referred to as a header file. The function definition tells the compiler how the function works. The function definition is called the implementation of the class method, and it is kept in a CPP file. The implementation details

of the class are of concern only to the author of the class. Clients of the class--that is, the parts of the program that use the class--don't need to know, and don't care, how the functions are implemented.

3.1.5 Inline Implementation

Just as you can ask the compiler to make a regular function inline, you can make class methods inline. The keyword Inline appears before the return value. The inline implementation of the Get Weight() function, for example, looks like this:

```
inline int Cat::GetWeight()
        {
return its Weight;              // return the Weight data member
        }
```

You can also put the definition of a function into the declaration of the class, which automatically makes that function inline. For example,

```
class Cat
{
public:
int Get Weight() { return its Weight; }     // Inline
void Set Weight(int aWeight);
};
```

Note the syntax of the GetWeight( ) definition. The body of the inline function begins immediately after the declaration of the class method; there is no semicolon after the parent-theses. Like any function, the definition begins with an opening brace and ends with a closing brace. As usual, white space doesn't matter; you could have written the declaration as

```
class Cat
{
 public:
int Get Weight()
{
return its Weight;      // inline
void Set Weight(int aWeight);
};
```

Listings 5.3 and 5.4 re-create the Cat class, but they put the declaration in CAT.HPP and the implementation of the functions in CAT.CPP. Listing 5.4 also changes the accessor/mutator functions and the Meow() function to inline.

Listing 5.3. Cat class declaration in CAT.HPP

```
1:  #include <iostream.h>
2:  class Cat
3:  {
4:  public:
5:  Cat (int initialAge);
6:  ~Cat();
7:  int GetAge() { return itsAge;}              // inline!
8:  void SetAge (int age) { itsAge = age;}     // inline!
9:  void Meow() { cout << "Meow.\n";}          // inline!
10: private:
11: int itsAge;
12. };
```

Listing 5.4. Cat implementation in CAT.CPP.

```
1:  // Demonstrates inline functions
2:  // and inclusion of header files
3:
4:  #include "cat.hpp" // be sure to include the header files!
5:
6:
7:  Cat::Cat(int initialAge)       //constructor
8.  {
9:  itsAge = initialAge;
10: }
11:
12: Cat::~Cat() //destructor, takes no action
13: {
14: }
15:
16: // Create a cat, set its age, have it
17: // meow, tell us its age, then meow again.
18: int main()
19: {
20: Cat Frisky(5);
21: Frisky.Meow();
22: cout << "Frisky is a cat who is "
23: cout << Frisky.GetAge() << " years old. In “;
24: Frisky.Meow();
25: Frisky.SetAge(7);
26: cout << "Now Frisky is " ;
27: cout << Frisky.GetAge() << "   years old. In ” ;
28: return 0;
29: }
```

Output: Meow.
Frisky is a cat who is 5 years old. Meow.
Now Frisky is 7 years old.

Analysis: The code presented in Listing 5.3 and Listing 5.4 is similar to the code in Listing 5.1, except that three of the methods are written

inline in the declaration file and the declaration has been separated into CAT.HPP.
GetAge() is declared in line 7, and its inline implementation is provided. Lines 8 and 9 provide more inline functions, but the functionality of these functions is unchanged froth the previous "outline" implementations.

Line 4 of Listing 5.4 shows #include "cat.hpp", which brings in the listings from CAT.HPP. By including cat.hpp, you have told the precompiled to read cat.hpp into the file as if it had been typed there, starting on line 5.

This technique allows you to put your declarations into a different file from your implementation, yet have that declaration available when the compiler needs it. This is a very common technique in C++ programming. Typically, class declarations are in an HPP file that is then #included into the associated CPP file.

Lines 18-29 repeat the main function from Listing 5.1. This shows that making these functions inline doesn't change their performance.

3.2 Class Composition

It is not uncommon to build up build up a complex class by declaring simpler classes and including them in the declaration of the more complicated class. The method of declaration is called class composition. For example, you might declare a wheel class, a mother class, a transmission class, and so forth, and then combine them into a car class. This declares a has-a relationship. A car motor, it has wheel, and it has a transmission

Consider a second example. A rectangle is composed of lines. A line is defined by two points. A point is defined by an x-coordinate and a y-coordinate. Listing 5.5 shown a complete declaration of a Rectangle class, as might appear in RECTANGLE. HPP because a rectangle is defined as four lines connecting four point and each point refers to a coordinate eon a graph, we first declare a Point class, to hold the x,y coordinates of each point . Listing 5.6 shown a complete declaration of both classes.

Listing 5.5 Declaring a complete class.

```
1:    // Begin Rect. Hpp
2:    #include <iostream.h>
3:    class point          // holds x, y coordinates
```

```
4:      {
5:      // no constructor, use default
6:      public:
7:      viod setX(int  x )      {itsX = x ; }
8:      viod SetY(int y)        { itsY = y ; }
9:      int GetX ( ) const      { return itsX ; }
10:     int GetY ( ) const      { return itsY ; }
11:     Private:
12:             int itsX;
13:             int itsY ;
14:     } ;     // end of point class declaration
15:
16:
17:     class Rectangle
18:     {
19:     public
20:     Rectangle ( int top, int left, int bottom,  int right) ;
21:     ~ Rectangle  ( )  { }
22:
23:     int GetTop ( ) const { return itsTop; }
24:     int GetLeft  ( ) const { return itsLeft; }
25:     int GetBottom ( ) const { return its Top; }
26:     int GetRight( ) const { return its Top; }
27:
28:     Point GetUperLeft  ( ) const { return itsUpperLeft; }
29:     Point GetLowerLeft  ( ) const { return itsLowerLeft; }
30:     Point GetUpperRight  ( ) const { return itsUpperRight; }
31:     Point GetLowerRight   ( ) const { return itsLowerRight; }
32:
33:     viod SetUpperLeft (point Location)  { itsUpperLeft = Location ;}
34:     viod SetLowerLeft ( point Location0 [ itsLowerLeft = Location
;}
35:     void SetUpperRight(Point Location) (itsUpperRight = Location;}
36:     void SetLowerRight(Point Location) (itsLowerRight =
Location;}
37:
38:     void SetTop(int top) ( itsTop = top; }
39:     void SetLeft (int left) ( itsLeft = left; }
40:     void SetBottom (int bottom) ( itsBottom = bottom; 1
41:     void SetRight (int right) ( itsRight = right; 1
42:
43:     int GetArea() const;
44:
45:     private:
46:     Point itsUpperLeft;
47:     Point itsUpperRight;
```

```
48:     Point itsLowerLeft;
49:     Point itsLowerRight;
50:     int itsTop;
51:     int itsLeft;
52:      int itsBottom;
53:     int itsRight;
54.     };
55:      // end Rect.hpp Listing
5.6.    RECT.CPP.

1:      // Begin rect.cpp
2:      #include "rect.hpp"
3:      Rectangle::Rectangle(int top, int left, int bottom, int right) 4: (
5:      itsTop = top;
6:      itsLeft = left;
7:      itsBottom = bottom;
8:      itsRight = right; 9:
10:      itsUpperLeft.SetX(left);
11:      itsUpperLeft.SetY(top); 12:
13:      itsUpperRight.SetX(right);
14:     itsUpperRight.SetY(top); 15:
16:     itsLowerLeft.SetX(left);
17:      itsLowerLeft.SetY(bottom);
18:
19:      itsLowerRight.SetX(right);
20:      itsLowerRight.SetY(bottom); 21: 1
22:
23:
24:      // compute area of the rectangle by finding corners,
25:      // establish width and height and then multiply
26:     int Rectangle::GetArea() const
27:
28:     int Width = itsRight-itsLeft;
29:     int Height = itsTop - itsBottom;
30:     return (Width * Height);
31:      1
32:
33.     int main()
34.     1
35.     //initialize a local Rectangle variable
36.     Rectangle My Rectangle (100, 20, 50, 80 );
37.
38.     int Area = MyRectangle.GetArea();
39.
        40.      cout << "Area: "
41.     cout << "Upper Left X Coordinate: ";
```

```
42.     cout << MyRectangle.GetUpperLeft().GetX()
43.     return 0;
44.     }
```

Output: Area: 3000
Upper Left X Coordinate: 20

Analysis: Lines 3-14 in Listing 5.5 declare the class Point, which is used to hold a specific x,y coordinate on a graph. As written, this program doesn't use Points much. However, other drawing methods require Points.

Within the declaration of the class Point, you declare two member variables (itsX and itsY) on lines 12 and 13. These variables hold the values of the coordinates. As the x-coordinate increases, you move to the right on the graph. A s the y-coordinate increases, you move upward on the graph. Other graphs use different systems. Some windowing programs, for example, increase the y-coordinate as you move down in the window. The Point class uses inline accessor/mutator functions to get and set the X and Y points declared on lines 7-10. Points use the default constructor and destructor. Therefore, you must set their coordinates explicitly. Line 17 begins the declaration of a Rectangle class. A Rectangle consists of four points that represent the corners of the Rectangle.

The constructor for the Rectangle (line 20) takes four integers, known as top, left, bottom, and right. The four parameters to the constructor are copied into four member variables (Listing 5.6) and then the four Points are established.

In addition to the usual accessor/mutator functions, Rectangle has a function GetArea() declared in line 43. Instead of storing the area as a variable, the GetArea() function computes the area on lines 28-29 of Listing 5.6. To do this, it computes the width and the height of the rectangle, and then it multiplies these two values. Getting the x-coordinate of the upper-left corner of the rectangle requires that you access the Upper Left point, and ask that point for its X value. Because GetUpperLeft()is ()a method of Rectangle, it can directly access the private data of Rectangle, including itsUpperLeft. Because itsUpperLeft is a Point and

Point's itsX value is private, GetUpperLeft() cannot directly access this data. Rather, it must use the public accessor/mutator function GetX( ) to obtain that value.Line 33 of Listing 5.6 is the beginning of the body of the actual program. Until line 36, no memory has been allocated, and nothing has really happened. The only thing you've done is tell the

compiler how to make a point and how to make a rectangle, in case one is ever needed.

In line 36, you define a Rectangle by passing in values for Top, Left, Bottom, and Right.

In line 38, you make a local variable, Area, of type int. This variable holds the area of the Rectangle that you've created. You initialize Area with the value returned by Rectangle's GetArea( ) function.A client of Rectangle could create a Rectangle object and get its area without ever looking at the implementation of GetArea( )

.

RECT.HPP is shown in Listing 5.5. Just by looking at the header file, which contains the declaration of the Rectangle class, the programmer knows that GetAreaO returns an int. How GetAreaO does its magic is not of concern to the user of class Rectangle. In fact, the author of Rectangle could change GetAreaO without affecting the programs that use the Rectangle class.

3.3 Structures

A very close cousin to the class keyword is the keyword strut, which is used to declare a structure. In C++, a structure is exactly like a class, except that its members are public by default. You can declare a structure exactly as you declare a class, and you can give it exactly the same data members and functions. In fact, if you follow the good programming practice of always explicitly declaring the private and public sections of your class, there will be no difference whatsoever.

Try re-entering Listing 5.5 with these changes:

- In line 3, change class Point to strut Point.
- In line 17, change class Rectangle to strut Rectangle.

Now run the program again and compare the output. There should be no change.

3.3.1 Why Two Keywords Do the Same Thing

You're probably wondering why two keywords do the same thing. This is an accident of history. When C++ was developed, it was built as an extension of the C language. C has structures, although C structures don't have class methods. Bjarne Structure, the creator of C++, built upon struts, but he changed the name to class to represent the new, expanded functionality.

DO put your class declaration in an HPP file and your member functions in a CPP file. **DO** use const whenever you can.
DO understand classes before you move on.

4.0 CONCLUSION

Constructors and destructors give classes the power it wields. This unit has introduced you to some concepts that enabled you to extend your C++ compiler and work in an environment that is suitable for the nature of your software development.

5.0 SUMMARY

Class constructors initialize objects. Class destructors destroy objects and are often used to free memory allocated by methods of the class.
It is good programming practice to isolate the interface, or declaration, of the implementation of the class methods is written in a file with a CPP extension.

6.0 TUTOR-MARKED ASSIGNMENT

l. If using a const function to change the class causes a compiler error, why shouldn't I just leave out the word const and be sure to avoid errors?
2. What do you understand as class composition
3. Explain the importance of the keyword: inline
4. Is there ever a reason to use a structure in a C++ program?
5. Describe the functions of constructors and destructors.
6. What are access modifiers?
7. Write the code that declares a class called Employee with these data members: age, years Of Service, and Salary.
    - Write your own constructor and destructor for the class
    - Use the right access modifiers for the members
    - Use the appropriate accessor and mutator methods

7.0 REFERENCES/FURTHER READING

Teach Yourself C++ in 21 days, Greg Wiegand, **http://www.mcp.com**

Borland C++ Object-Oriented Programming