Sengamala Thayaar Educational Trust Women's College

(Affiliated to Bharathidasan University)

(Accredited with 'A' Grade {3.45/4.00} By NAAC) (An ISO 9001: 2015 Certified Institution)

Sundarakkottai, Mannargudi-614 016.
Thiruvarur (Dt.), Tamil Nadu, India.

PROGRAMMING IN C++

R.AKILANDESWARI

ASSISTANT PROFESSOR

PG & RESEARCH DEPARTMENT OF COMPUTER SCIENCE

UNIT - V

THE C++ STANDARD TEMPLATE LIBRARY (STL)

The Standard Template Library (STL) is a set of C++ template classes to provide common programming data structures and functions such as lists, stacks, arrays, etc. It is a library of container classes, algorithms, and iterators. It is a generalized library and so, its components are parameterized. A working knowledge of template classes is a prerequisite for working with STL.

STL has four components

- Algorithms
- Containers
- Functions
- Iterators

Algorithms

he header algorithm defines a collection of functions especially designed to be used on ranges of elements.They act on containers and provide means for various operations for the contents of the containers.

- Algorithm
  - Sorting
  - Searching
  - Important STL Algorithms
  - Useful Array algorithms
  - Partition Operations
- Numeric
  - valarray class

Containers

Containers or container classes store objects and data. There are in total seven standard "first-class" container classes and three container adaptor classes and only seven header files that provide access to these containers or container adaptors.

- Sequence Containers: implement data structures which can be accessed in a sequential manner.
  - vector
  - list
  - deque

    - arrays
    - forward_list

- Container Adaptors : provide a different interface for sequential containers.
    - queue
    - priority_queue
    - stack
- Associative Containers : implement sorted data structures that can be quickly searched (O(log n) complexity).
    - set
    - multiset
    - map
    - multimap
- Unordered Associative Containers : implement unordered data structures that can be quickly searched
    - unordered_set
    - unordered_multiset
    - unordered_map
    - unordered_multimap

Functions

The STL includes classes that overload the function call operator. Instances of such classes are called function objects or functors. Functors allow the working of the associated function to be customized with the help of parameters to be passed.

- Functors

Iterators

As the name suggests, iterators are used for working upon a sequence of values. They are the major feature that allow generality in STL.

- Iterators

Utility Library

Defined in header <utility>.

- pair

example program

```
#include <iostream>
```

```
#include <vector>
using namespace std;

int main() {

   // create a vector to store int
   vector<int> vec;
   int i;

   // display the original size of vec
   cout << "vector size = " << vec.size() << endl;

   // push 5 values into the vector
   for(i = 0; i < 5; i++) {
      vec.push_back(i);
   }

   // display extended size of vec
   cout << "extended vector size = " << vec.size() << endl;

   // access 5 values from the vector
   for(i = 0; i < 5; i++) {
      cout << "value of vec [" << i << "] = " << vec[i] << endl;
   }

   // use iterator to access the values
   vector<int>::iterator v = vec.begin();
   while( v != vec.end()) {
      cout << "value of v = " << *v << endl;
      v++;
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
vector size = 0
extended vector size = 5
value of vec [0] = 0
value of vec [1] = 1
value of vec [2] = 2
value of vec [3] = 3
value of vec [4] = 4
value of v = 0
value of v = 1
value of v = 2
```

value of v = 3
value of v = 4

Here are following points to be noted related to various functions we used in the above example −

- The push_back( ) member function inserts value at the end of the vector, expanding its size as needed.
- The size( ) function displays the size of the vector.
- The function begin( ) returns an iterator to the start of the vector.
- The function end( ) returns an iterator to the end of the vector.

MANIPULATING STRINGS

C++ provides following two types of string representations −

- The C-style character string.
- The string class type introduced with Standard C++.

The C-Style Character String

The C-style character string originated within the C language and continues to be supported within C++. This string is actually a one-dimensional array of characters which is terminated by a **null** character '\0'. Thus a null-terminated string contains the characters that comprise the string followed by a **null**.

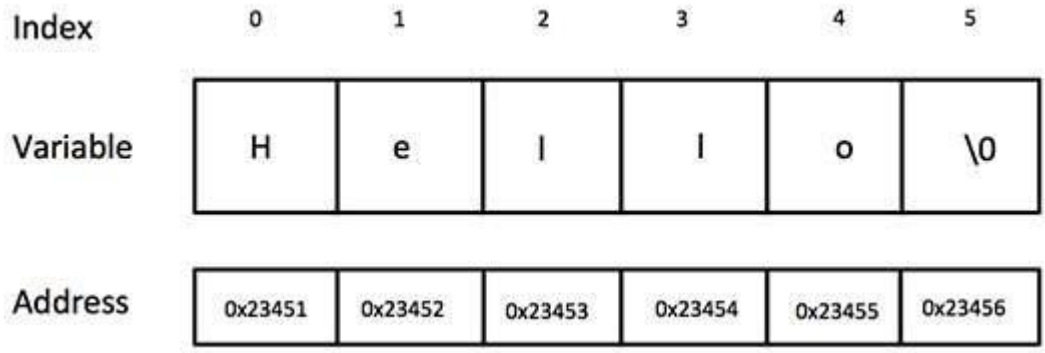
The following declaration and initialization create a string consisting of the word "Hello". To hold the null character at the end of the array, the size of the character array containing the string is one more than the number of characters in the word "Hello."

```
char greeting[6] = {'H', 'e', 'l', 'l', 'o', '\0'};
```

If you follow the rule of array initialization, then you can write the above statement as follows −

```
char greeting[] = "Hello";
```

Following is the memory presentation of above defined string in C/C++ −



Actually, you do not place the null character at the end of a string constant. The C++ compiler automatically places the '\0' at the end of the string when it initializes the array. Let us try to print above-mentioned string −

Live Demo

```
#include <iostream>

using namespace std;

int main () {

   char greeting[6] = {'H', 'e', 'l', 'l', 'o', '\0'};

   cout << "Greeting message: ";
   cout << greeting << endl;

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Greeting message: Hello
```

C++ supports a wide range of functions that manipulate null-terminated strings −

Sr.No	Function & Purpose
1	**strcpy(s1, s2);** Copies string s2 into string s1.
2	**strcat(s1, s2);** Concatenates string s2 onto the end of string s1.
3	**strlen(s1);** Returns the length of string s1.
4	**strcmp(s1, s2);** Returns 0 if s1 and s2 are the same; less than 0 if s1<s2; greater than 0 if s1>s2.

5	**strchr(s1, ch);** Returns a pointer to the first occurrence of character ch in string s1.
6	**strstr(s1, s2);** Returns a pointer to the first occurrence of string s2 in string s1.

Following example makes use of few of the above-mentioned functions −

Live Demo

```
#include <iostream>
#include <cstring>

using namespace std;

int main () {

   char str1[10] = "Hello";
   char str2[10] = "World";
   char str3[10];
   int  len ;

   // copy str1 into str3
   strcpy( str3, str1);
   cout << "strcpy( str3, str1) : " << str3 << endl;

   // concatenates str1 and str2
   strcat( str1, str2);
   cout << "strcat( str1, str2): " << str1 << endl;

   // total lenghth of str1 after concatenation
   len = strlen(str1);
   cout << "strlen(str1) : " << len << endl;

   return 0;
}
```

When the above code is compiled and executed, it produces result something as follows −

```
strcpy( str3, str1) : Hello
strcat( str1, str2): HelloWorld
strlen(str1) : 10
```

The String Class in C++

The standard C++ library provides a **string** class type that supports all the operations mentioned above, additionally much more functionality. Let us check the following example −

Live Demo

```
#include <iostream>
#include <string>

using namespace std;

int main () {

   string str1 = "Hello";
   string str2 = "World";
   string str3;
   int  len ;

   // copy str1 into str3
   str3 = str1;
   cout << "str3 : " << str3 << endl;

   // concatenates str1 and str2
   str3 = str1 + str2;
   cout << "str1 + str2 : " << str3 << endl;

   // total length of str3 after concatenation
   len = str3.size();
   cout << "str3.size() :  " << len << endl;

   return 0;
}
```

When the above code is compiled and executed, it produces result something as follows −

```
str3 : Hello
str1 + str2 : HelloWorld
str3.size() :  10
```

In the object-oriented approach, the focus is on capturing the structure and behavior of information systems into small modules that combines both data and process. The main aim of Object Oriented Design (OOD) is to improve the quality and productivity of system analysis and design by making it more usable.

In analysis phase, OO models are used to fill the gap between problem and solution. It performs well in situation where systems are undergoing continuous design, adaption, and maintenance. It identifies the objects in problem domain, classifying them in terms of data and behavior.

The OO model is beneficial in the following ways −

- It facilitates changes in the system at low cost.
- It promotes the reuse of components.
- It simplifies the problem of integrating components to configure large system.
- It simplifies the design of distributed systems.

Elements of Object-Oriented System

Let us go through the characteristics of OO System −

- **Objects** − An object is something that is exists within problem domain and can be identified by data (attribute) or behavior. All tangible entities (student, patient) and some intangible entities (bank account) are modeled as object.
- **Attributes** − They describe information about the object.
- **Behavior** − It specifies what the object can do. It defines the operation performed on objects.
- **Class** − A class encapsulates the data and its behavior. Objects with similar meaning and purpose grouped together as class.
- **Methods** − Methods determine the behavior of a class. They are nothing more than an action that an object can perform.
- **Message** − A message is a function or procedure call from one object to another. They are information sent to objects to trigger methods. Essentially, a message is a function or procedure call from one object to another.

Features of Object-Oriented System

An object-oriented system comes with several great features which are discussed below.

Encapsulation

Encapsulation is a process of information hiding. It is simply the combination of process and data into a single entity. Data of an object is hidden from the rest of the system and available only through the services of the class. It allows improvement or modification of methods used by objects without affecting other parts of a system.

Abstraction

It is a process of taking or selecting necessary method and attributes to specify the object. It focuses on essential characteristics of an object relative to perspective of user.

Relationships

All the classes in the system are related with each other. The objects do not exist in isolation, they exist in relationship with other objects.

There are three types of object relationships −

- **Aggregation** − It indicates relationship between a whole and its parts.
- **Association** − In this, two classes are related or connected in some way such as one class works with another to perform a task or one class acts upon other class.
- **Generalization** − The child class is based on parent class. It indicates that two classes are similar but have some differences.

Inheritance

Inheritance is a great feature that allows to create sub-classes from an existing class by inheriting the attributes and/or operations of existing classes.

Polymorphism and Dynamic Binding

Polymorphism is the ability to take on many different forms. It applies to both objects and operations. A polymorphic object is one who true type hides within a super or parent class.

In polymorphic operation, the operation may be carried out differently by different classes of objects. It allows us to manipulate objects of different classes by knowing only their common properties.

Structured Approach Vs. Object-Oriented Approach

The following table explains how the object-oriented approach differs from the traditional structured approach −

Structured Approach	Object Oriented Approach
It works with Top-down approach.	It works with Bottom-up approach.
Program is divided into number of submodules or functions.	Program is organized by having number of classes and objects.
Function call is used.	Message passing is used.
Software reuse is not possible.	Reusability is possible.
Structured design programming usually left until end phases.	Object oriented design programming done concurrently with other phases.
Structured Design is more suitable for offshoring.	It is suitable for in-house development.

It shows clear transition from design to implementation.	Not so clear transition from design to implementation.
It is suitable for real time system, embedded system and projects where objects are not the most useful level of abstraction.	It is suitable for most business applications, game development projects, which are expected to customize or extended.
DFD & E-R diagram model the data.	Class diagram, sequence diagram, state chart diagram, and use cases all contribute.
In this, projects can be managed easily due to clearly identifiable phases.	In this approach, projects can be difficult to manage due to uncertain transitions between phase.

Unified Modeling Language (UML)

UML is a visual language that lets you to model processes, software, and systems to express the design of system architecture. It is a standard language for designing and documenting a system in an object oriented manner that allow technical architects to communicate with developer.

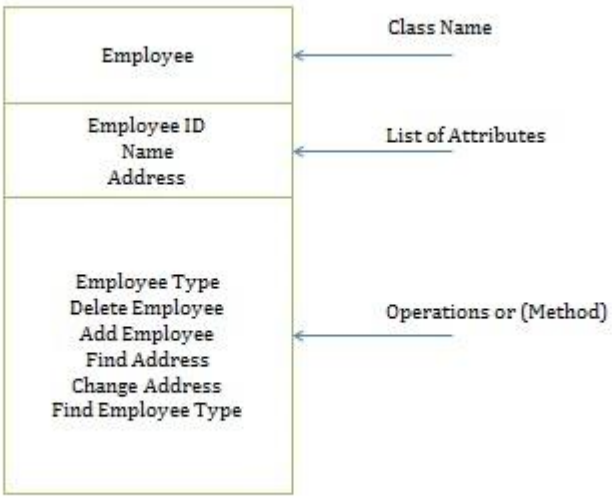
It is defined as set of specifications created and distributed by Object Management Group. UML is extensible and scalable.

The objective of UML is to provide a common vocabulary of object-oriented terms and diagramming techniques that is rich enough to model any systems development project from analysis through implementation.

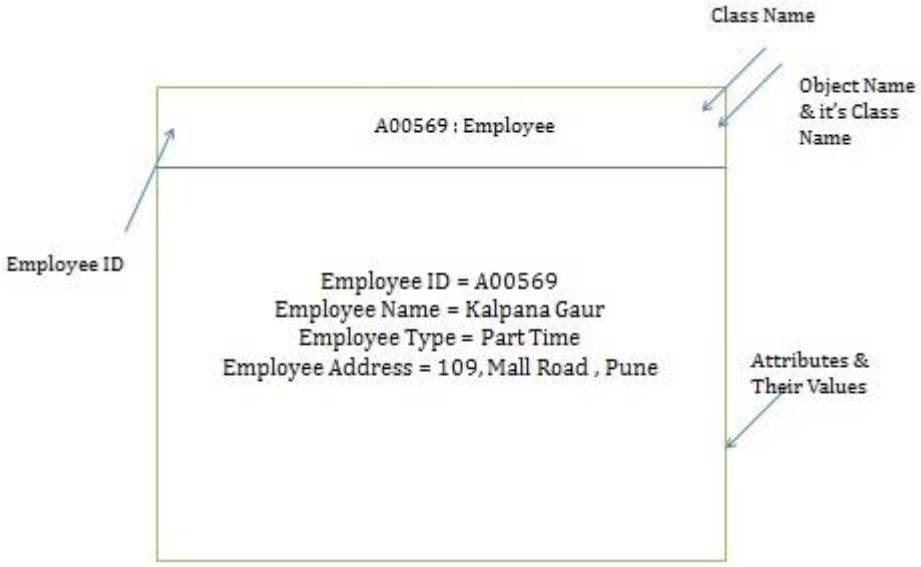
UML is made up of −

- **Diagrams** − It is a pictorial representations of process, system, or some part of it.
- **Notations** − It consists of elements that work together in a diagram such as connectors, symbols, notes, etc.

Example of UML Notation for class



Instance diagram-UML notation



Operations Performed on Objects

The following operations are performed on the objects −

- **Constructor/Destructor** − Creating new instances of a class and deleting existing instances of a class. For example, adding a new employee.
- **Query** − Accessing state without changing value, has no side effects. For example, finding address of a particular employee.

- **Update** − Changes value of one or more attributes & affect state of object For example, changing the address of an employee.

Uses of UML

UML is quite useful for the following purposes −

- Modeling the business process
- Describing the system architecture
- Showing the application structure
- Capturing the system behavior
- Modeling the data structure
- Building the detailed specifications of the system
- Sketching the ideas
- Generating the program code

Static Models

Static models show the structural characteristics of a system, describe its system structure, and emphasize on the parts that make up the system.

- They are used to define class names, attributes, methods, signature, and packages.
- UML diagrams that represent static model include class diagram, object diagram, and use case diagram.

Dynamic Models

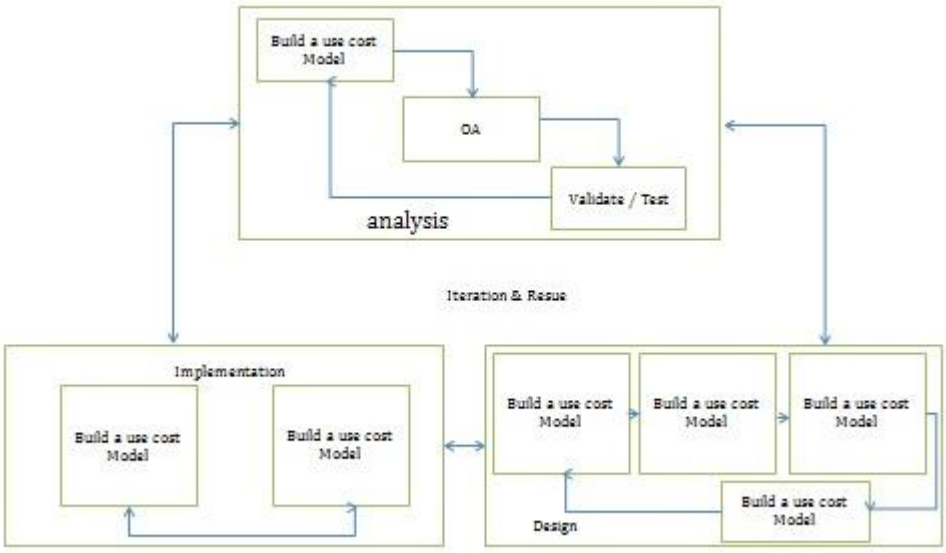
Dynamic models show the behavioral characteristics of a system, i.e., how the system behaves in response to external events.

- Dynamic models identify the object needed and how they work together through methods and messages.
- They are used to design the logic and behavior of system.
- UML diagrams represent dynamic model include sequence diagram, communication diagram, state diagram, activity diagram.

Object Oriented System Development Life Cycle

It consists of three macro processes −

- Object Oriented Analysis (OOA)
- Object oriented design (OOD)
- Object oriented Implementation (OOI)



Object Oriented Systems Development Activities

Object-oriented systems development includes the following stages −

- Object-oriented analysis
- Object-oriented design
- Prototyping
- Implementation
- Incremental testing

Object-Oriented Analysis

This phase concerns with determining the system requirements and to understand the system requirements build a **use-case model**. A use-case is a scenario to describe the interaction between user and computer system. This model represents the user needs or user view of system.

It also includes identifying the classes and their relationships to the other classes in the problem domain, that make up an application.

Object-Oriented Design

The objective of this phase is to design and refine the classes, attributes, methods, and structures that are identified during the analysis phase, user interface, and data access. This phase also identifies and defines the additional classes or objects that support implementation of the requirement.

Prototyping

Prototyping enables to fully understand how easy or difficult it will be to implement some of the features of the system.

It can also give users a chance to comment on the usability and usefulness of the design. It can further define a use-case and make use-case modeling much easier.

Implementation

It uses either Component-Based Development (CBD) or Rapid Application Development (RAD).

Component-based development (CBD)

CODD is an industrialized approach to the software development process using various range of technologies like CASE tools. Application development moves from custom development to assembly of pre-built, pre-tested, reusable software components that operate with each other. A CBD developer can assemble components to construct a complete software system.

Rapid Application Development (RAD)

RAD is a set of tools and techniques that can be used to build an application faster than typically possible with traditional methods. It does not replace SDLC but complements it, since it focuses more on process description and can be combined perfectly with the object oriented approach.

Its task is to build the application quickly and incrementally implement the user requirements design through tools such as visual basic, power builder, etc.

Incremental Testing

Software development and all of its activities including testing are an iterative process. Therefore, it can be a costly affair if we wait to test a product only after its complete development. Here incremental testing comes into picture wherein the product is tested during various stages of its development.