C++ and Object-Oriented Programming

Introduction to Programming

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- Structure programming and object oriented programming
- C++ features
- Classes

Computer System Development

- Computer hardware is getting very powerful nowadays
  - Hardware cost has been driven down very significantly
  - Thanks for Moore's Law and talented electrical engineers
  - General purpose processors for most applications
- Application software development has seen significant progress as well, but to a lesser extent
  - Software cost dominates in many applications
  - Software plays the role of product differentiation as well
  - Software programs sustained for a long time
  - Software maintenance and upgrade are crucial in many applications

Software engineering progress

- High level languages
- Library for reuse
- Structured programming
  - Readability and maintenance
  - Basic components are functions
    - To solve a specific problem
  - C was developed with this intention
- Object-Oriented Programming
  - Basic components are objects that model real world counterparts
    - Attributes and operations –data and functions
  - Data hiding and implementation hiding
    - Users know how to use them but not how were they implemented
  - Reusability increases so is team work
    - Interface and implementation
  - C++ fits to this paradigm

Object Oriented Programming

- Define object attributes and operations
  - Data and functions
- Objects such defined can be reused in other projects
- Detailed data storage or function implementation need not be known to users
  - Only interface is known
  - Clear responsibility
  - Easier debugging
  - Enable team work
- Program still needs algorithmic description and implementation

C++ Source File and Compiler

- C++ source files have the file extension of `.cpp` instead of `.c`
  - C source files: `lab1.c`, `lab2.c`
  - C++ source files: `lab1.cpp`, `lab2.cpp`
- Header files have `.h` file extension
  - The same as C headers
- Compilation of C++ files
  - `g++ lab1.cpp`
    - Produce `a.out` program
  - `g++ -o lab1 lab1.cpp`
    - Produce `lab1` program
  - `g++ -c lab1.c`
    - Produce `lab1.o` file

C++ Input and Output

- Standard C printf and scanf functions are still available in C++
    - Need to #include <cstdio> header
- C++ provides additional input and output methods
    - cin >> identifier
        - input to an identifier
    - cout << expression
        - output to std output
    - Need to #include <iostream> header
    - Note cin needs no pointer
    - << and >> operators are overloaded
- Examples: exp1.cpp

```
cin >> i >> j;
cout << "Hello!\n" << "i=" << i;
```

Namespaces

- Two properties of a variable: storage duration and scope
- For large programs, it is not difficult to see that we may need many variables and functions
    - Name crashes can happen, especially in a large team
- C++ provides a way to manage variable scopes - namespace
    - variable in a name space can be referenced by :: operator
    - using preprocessor can simplify accessing to these variables
- Examples: exp2.cpp, exp3.cpp

```
namespace mySpace {
    int i, j;
    double mysqrt(double);
}
```

Reference Parameters and Variables

- In addition to pass-by-value and pass-by-pointer schemes, C++ provides additional pass-by-reference scheme
- reference parameters of a function will not be copied and they occupy the same memory locations as the referenced variables
    - Value of the referenced variable can be changed
    - Function calls are more efficient
- reference variable within a function also serves as a alias to the referenced variable
    - Same memory location and same value
- The value of a reference variable needs no * operator
- Examples: exp4.cpp

```
void func(int i, int &j) ;    // j passed by reference
int i, &j = i;                // j is an alias to i
```

Functions with Default Parameters

- In C++ functions can have default arguments
- Default value is declared in function definition
- If a parameter is not provided by a function call, then the default value is taken for the parameter
- Only trailing parameters can be default parameters
- Example: exp5.cpp

```
void f(int a = 1, int b = 1, int c = 1) {
   // ...
}

// function calls
   f(i, j, k);
   f(i, j);
   f(i);
   f();
```

C++ and Classes

- The aim of the C++ class concept is to provide the programmer with a tool for creating new types that can be used as conveniently as the built-in types.
- A type is a concrete representation of a concept.
  - For example, float with its operations +, -, *, etc., provides a concrete approximation of the mathematical concept of a real number.
- A class is a user-defined type.
- A program that provides types that closely match the concepts of the application tends to be easier to understand and easier to modify than a program that does not.
- Example: exp6.cpp

C++ and Classes

- A well-chosen set of user-defined types makes a program more concise.
  - It also enables the compiler to detect illegal uses of objects that would otherwise remain undetected until the program is thoroughly tested.
- The fundamental idea in defining a new type is to separate the incidental details of the implementation from the properties essential to the correct use of it.
- Such a separation is best expressed by channeling all uses of the data structure and internal housekeeping routines through a specific interface.

Classes and Object-Oriented Programming

- In C++ classes are the basic components of a program
  - Data members for attributes
  - Function members for operations
- Example:

```
class Complex {
    public:
        Complex(double, double);    // constructor
        void printComplex(void);
        double getReal(void);
    private:
        double x, y;
};    // need ;
```

Class Definition

- Data members
  - Similar to struct's definition (struct itself is also a class)
  - Any type: basic or user-defined, including class
- Function members
  - Function declarations should be included
  - Function to operate on this class
- public members (data or functions) can be accessed by any functions
- private members (data or functions) can be accessed by member functions only
  - Non-member functions accessing private members is a compilation error
  - Private functions: utility functions

Access Control

- Private members can only be accessed by member functions
- Public members can be accessed by any functions
- A `struct` is a class with public members only
- Benefits of access control:
  - Easier debugging, localization is done before the program is even run
  - Change of the class needs to recompile the member functions only
  - Serve as documentation as well

Class Member Function Definitions

- Member functions' definition can be done within class declaration
- Function definition can also be done outside of class declaration
  - Need to prefix with classname and scope resolution operator `::`
- Member functions are invoked by
  - `object.memberfunction()`
  - `objectPtr->memberfunction()`
- `constructor`
  - Same name as class and no return type (or value)
- `destructor`
  - `~className`
  - Called explicitly or when variables are released
  - Destructors clean up and release resources
  - Destructors are called, for example, when automatic variables go out of scope

Class and Memory Allocation

- class similar to `struct` take actual memory space to store data
  - data member
- Member functions are not duplicated, only one copy exists
- `Static data` also has one copy only
- Similar to `struct`, `class` object can be assigned using `=`
  - Member-wise copying
  - Each member is copied from `rvalue` object to `lvalue` object

Class Header and Implementation Files

- Class definition and implementation can all be located in the same file as the `main` function
- In practice, for each object, a header file `.h` and an implementation file `.cpp` are usually created
  - Interface `.h` and implementation `.cpp` are separated
  - Class users need to know the interface but not the actual implementation
- Implementation source file needs not be provided.
  - Object file `.o` is sufficient to create final program
  - Hiding implementation from users
- With the header and object files, the class can be reused by other programs
- Limiting data member access to the member functions reduces possibility of program bugs

const Objects and const Member Functions

- Some objects are not changing and can be declared so by preceding a `const` keyword
    - Example:

```
const Complex One(1.0, 0.0);
```

- A member function is not allowed to operate on `const` object unless it is declared to be `const` —not modifying the data members
    - Example:

```
double getReal() const;
```

-
    - Compiler check if data members are modified or not
    - Further reduces possibility of bugs
- `const` data member must be initialized, not assigned, using initializer
    - Example: exp70.h , exp71.cpp , exp7.cpp

```
Complex(double r, double i) : x(r), y(i)
{  ... }
```

friend Functions and friend Classes

- A `friend` function is a nonmember function but allowed to access private data
- It needs to be declared in the class preceded with a `friend` keyword

```
class Complex {
        Complex(double, double); // member function
    private:
        double x, y;
    friend void reset(void);      // friend func, not member func
}
```

- If the member functions of a class (class2) are all friends to a class (class1), then declared class2 as a `friend` class of class1

```
friend class class2;    // inside of class1 def
```

- Friendship is granted not taken
- Friendship is not symmetric
- Friendship is not transitive

this Pointer and Member Functions

- Compiler creates an implicit pointer, this, that points to the object
- All data member can be accessed either directly or through this pointer
- Sometimes we want to return a reference to the updated object so the operations can be chained.

```
class_type & class::func() {
    // ...
    return *this;
}
```

- *this refers to the object of which the function is invoked.
  - this is a pointer to the object
- For const member function, this is

```
const X* this
```

- Example: exp80.h, exp81.cpp, exp8.cpp

static Members

- static member: a variable is part of a class but not part of an object
- There is only one copy of static variable, not one for each object
- Static member functions access to the members of a class not object
- Static members can be accessed using class name as the qualifier
- Static data and functions must be defined somewhere (data initialized)

```
class T {
    static int accessCount;
    static void incAccessCount(void) { accessCount++ };
}
//  ...
int T::accessCount = 0;
T::incAccessCount();
```

Dynamic Memory Allocation using new and delete

- C++ dynamic memory allocation is done by using new and new []
- Example:

```
int *a, *bArray;
a = new int;
bArray = new int[10];
```

- Free of allocated memory is done by using delete and delete []
- Example: exp9.cpp

```
delete a;
delete [] bArray;
```

Efficient User-Defined Types

- The following set of operations are typical for user-defined type:
  - A constructor to initialize the object
  - A set of functions to examine the data
  - A set of functions to manipulate the data
  - Copy function
  - A class for error handling
- Constructor and copy function

```
T a(x);      // initialization constructor for class T
T b = a;     // copy constructor
T c;         // uninitialization constructor
c = a;       // copy function
             // default to memberwise copying
```

Summary

- Software development and OO programming
- C++ source files and compilation
- C++ input and output
- Namespaces
- Reference parameters and variables
- new and delete
- Classes
- const object and member functions
- friend functions and friend classes
- this pointer and member functions
- Static members
- Class operations