CS2311 Computer Programming

LT12 Object Oriented Programming-II

Computer Science, City University of Hong Kong

Semester B 2022-23

Review

- Prerequisite: C-like struct and overload
- Class and objects: basic concepts and syntax
- Constructors and destructors

Review: Definition of *struct*

- A *composite data type* that groups a list of variables (possibly different types) under one name
- Variables are stored in a continuous memory areas
- Syntax and example:

```
struct typename {
       type1  member_var1;
       type2  member_var2;
       ...
};
```

```
struct StudentRecord {
       char   name[51];
       char   sid[9];
       float  GPA;
};
```

Review: struct initialization

- No memory is allocated when you *define* a struct
- When you declare a variable of a given struct type, enough memory is allocated for storing all struct members *contiguously*
- Example:

```
StudentRecord danny = {"Danny", "50123456", 80};
```

Review: Accessing Individual Members

- A member variable can be accessed with the use of the dot operator "."

```
peter.final += 10;
```

- Structure types can have the same member name without conflict

```
struct CS2311Student {
        char    sid[9];
        float   asg[3];
        float   lab[10];
        float   midterm;
        float   final;
};
```

```
struct CS6789Student {
        char    sid[9];
        float   asg[5];
        float   final;
};
```

```
CS2311Student peter;
cin >> peter.final;
CS6789Student danny;
cin >> danny.final;
```

Review: Example

```cpp
struct CS2311Student {
    int     sid;
    float   quiz;
    float   asg1;
    float   asg2;
};
```

```cpp
int main() {
  CS2311Student sr;
  cout << "Please enter your id, quiz, a1, and a2 marks\n";
  cin >> sr.id;
  cin >> sr.quiz;
  cin >> sr.asg1;
  cin >> sr.asg2;
  cout << sr.id << " cw:" << (sr.quiz+sr.asg1+sr.asg2)/3 << endl;
  return 0;
}
```

Review: Struct Pointer

- Struct pointer stores the memory address of the first byte of a struct variable

```
Date d;
d.year = 2022;
d.month = 11;
d.day = 7;
Date *dPtr = &d;
```

Address	Value	
0xa12	2022	d.year
0xa16	11	d.month
0xa1a	7	d.day
0xa1e	0xa12	dPtr

Review: Structure Pointer: Arrow Syntax

- Arrow syntax `->`: access structure members using pointer
- Example

```
Date d;
d.year=2022; d.month=11; d.day=7;

Date *dPtr = &d;
cout << dPtr->year << " " << dPtr->month << " " << dPtr->day << endl;

dPtr->day++;
dPtr->month-=2;
cout << dPtr->day << endl;
```

Review: Function Overload

- *Overloading*: two or more functions with the *same name* but *different implementations*

- Two or more functions are said to be overloaded if they differ in
  - the number of arguments, OR
  - the type of arguments, OR
  - the order of arguments

- When an overloaded function is called, the compiler determines the most appropriate call by comparing function argument types

Review: Overload: Common Errors

```
int sum(int x, int y) {
    return x+y;
}
int sum(int a, int b) {
    return x+y;
}
int main() {
    int a, b;
    cin >> a >> b;
    cout << sum(a, b);
    return 0;
}
```

```
int sum(int x, int y) {
    return x+y;
}
char sum(int x, int y) {
    return '0'+(char)(x+y);
}
int main() {
    int a, b;
    cin >> a >> b;
    char s = sum(a, b);
    cout << s;
    return 0;
}
```

Review: Overload: Ambiguous Call

- Ambiguous call: when the compiler is unable to choose between two correctly overloaded functions

- Automatic type conversions are the main cause of ambiguity

```
void printData(double x) {
    cout << "Print double: " << x << endl;
}
void printData(float x) {
    cout << "Print float: " << x << endl;
}
int main() {
    char a = '0';
    printData(a);   printData((double)a);
    return 0;
}
```

Review: Class and Objects

- A *class* is a user-defined data type used as a template for creating *objects*

- For example
  - class: Politician   objects: Trump, Biden, Obama
  - class: Country   objects: China, India …

- A class typically contains:
  - *data fields*: member variables that describe object state (i.e., object attributes or properties)
  - *methods*: member functions that operate on the object (e.g., alter or access object state)

Review: Example

```
char     *body_color;
char     *eye_color;
float     pos_x, pos_y;
float     orient;
float     powerLevel;
Camera    eye;
Speaker   mouth;
Mic       ear;
```

```
void  start();
void  shutdown();
void  moveForward(int step);
void  turnLeft(int degree);
void  turnRight(int degree);
void  listen(Audio *audio);
Audio speak(char *str);
```

class: Robot

Member variables

Member functions

```
Robot eve, wall_e;
eve.body_color ="White";
eve.eye_color = "Blue";
wall_e.body_color = "Yellow";
wall_e.eye_color = "Black";
...
```

Review: Object-Oriented Programming (OOP)

- Conventional procedural programming:
  - ➢ A program is divided into small parts called functions
  - ➢ Focus on solving a problem step by step

- Object-oriented programming
  - ➢ A program is divided into objects, each contains data and functions that describe properties, attributes, and behaviours of the object
  - ➢ Focus on modelling object interactions in real-world
  - ➢ Code reuse, modularity and flexibility, efficient for large projects
  - ➢ However, it's not universally applicable to all problems

Review: `this` Pointer

- `this` keyword in C++ is *an implicit pointer that points to the object of which the member function is called*
- Every object has its own `this` pointer. Every object can reference itself by `this` pointer
- Usage: resolve shadowing, access currently executing object

```
class Circle {
public: // access specifier, introduced later
   float x, y, r;

   void setCenter(float x, float y) {
      this->x = x;
      this->y = y;
   }
   void setRadius(float r) {
      this->r = r;
   }
};
```

Review: Constructor

- A constructor is a special member function that initializes member variables
- A constructor is automatically called when an object of that class is declared
- Rule I: a constructor must have the same name as the class
- Rule II: a constructor definition cannot return a value

Review: Constructor: Example-I

```cpp
class Circle {
public: //  access specifier, introduced later
   float x, y, r;

   Circle() {
      cout << "Input center:\n";
      cin >> x >> y;
      cout << "Input radius:\n";
      cin >> r;
   }

};
```

```cpp
int main() {
   Circle *a = new Circle();
   delete a;

   Circle b;  //  Circle() will be called

   return 0;
}
```

Review: Constructor: Example-II

```cpp
class Circle {
public: //  access specifier, introduced later
   float x, y, r;

   Circle(float x0, float y0, float r0) {
      x = x0; y = y0; r = r0;
   }

};
```

```cpp
int main() {
   Circle a(0, 0, 1);

   Circle *b = new Circle(1, 1, 2);
   delete b;

   //  Note: A constructor cannot be called in the same
   //  way as an ordinary member function is called
   a.Circle(1, 1, 1); //  illegal

   return 0;
}
```

Review: Constructor: Example-III

- Constructor is typically overloaded, which allows objects to be initialized in multiple ways

```
class Circle {
public: //  access specifier, introduced later
   float x, y, r;
   Circle() {
      cout << "Input center and radius:\n";
      cin >> x >> y >> r;
   }
   Circle(float x0, float y0, float r0) {
      x = x0; y = y0; r = r0;
   }
};
```

```
int main() {
   Circle *a = new Circle();
   delete a;

   Circle b(0, 0, 1);

   Circle c; //  Circle() will be called
   // A constructor behaves like a function that
   // returns an object of its class type
   c = Circle(1, 1, 2);

   return 0;
}
```

Review: Default Constructor

- The constructor with no parameters is the default constructor
- A default constructor will be generated by compiler automatically if NO constructor is defined

```cpp
class Circle {
public: //  access specifier, introduced later
    float x, y, r;

    void setCenter() {
        cout << "Input center:\n";
        cin >> x >> y;
    }
    void setRadius() {
        cout << "Input radius:\n";
        cin >> r;
    }
};
```

```cpp
int main() {
    Circle a; //  although no constructor is defined,
              //  the compiler will add an empty Circle()
              //  automatically, and call it when a
              //  Circle object is allocated

    a.setCenter();
    a.setRadius();

    return 0;
}
```

Review: Initializer List

- The list of members to be initialized is indicated with constructor as a comma-separated list followed by a colon.

```
class Circle {
public: //  access specifier, introduced later
   float x, y, r;

   Circle(int x, int y, int r):x(x), y(y), r(r) {}

   //  while is equivalent to
   // Circle(int x0, int y0, int r0) {
   //    x = x0; y = y0; r = r0;
   // }
};
```

Review: Initializer List

- const and reference member variables MUST be initialized using initializer list

```
class myClass {
public: //  access specifier, introduced later
    const int t1;
    int& t2;

    //  Initializer list must be used
    myClass(int t1, int& t2):t1(t1), t2(t2) {}

    int getT1() { return t1; }
    int getT2() { return t2; }
};
```

```
int main() {
    int myint = 34;

    myClass c(10, myint);

    cout << c.getT1() << endl;
    cout << c.getT2() << endl;

    return 0;
}
```

Review: Destructor

- A destructor is a special member function which is invoked automatically whenever an object is going to be destroyed
- Rule-I: a destructor has the same name as their class name preceded by a tiled (~) symbol
- Rule-II: a destructor has no return values and parameters
  - destructor overload is NOT allowed
- Statically allocated objects are destructed when the object is out-of-scope
- Dynamically allocated objects are destructed only when you delete them

Review: Destructor: Example

```cpp
class Robot {
public: //  access specifier, introduced later
    char *name = NULL;
    Robot(char *name) {
        int n = strlen(name);
        this->name = new char[n+1];
        strncpy(this->name, name, n);
        this->name[n] = '\0';
        cout << "Constructing " << name << endl;
    }
    ~Robot() {
        cout << "Destructing " << name << endl;
        //  it's a good practice to free memories allocated
        //  for member variables in destructor
        delete name;
    }
};
```

```cpp
void func() {
    Robot eve("Eve");
    cout << "func is about to return\n";
    //  Automatically calls the destructor when a
    //  statically allocated  object is out of the
    //  scope
}

int main() {
    Robot *wall_e = new Robot("Wall-e");
    func();
    //  A  dynamically allocated object is destructed
    //  only when you explicitly delete it
    delete wall_e;
    cout << "main is about to return\n";
    return 0;
}
```

Outline

- Access specifier: public, protect, and private
- Inheritance
- Operator overloading
- Polymorphism

Access Specifier

- An access specifier defines how the members (data fields and methods) of a class can be accessed
- public: members are accessible from outside the class
- private: members cannot be accessed from outside the class
- protected: members cannot be accessed from outside the class.

  However, they can be accessed in inherited classes (later)
- By default, member variables and functions are private if no access specifiers are provided

Access Specifier: Example

```cpp
class Actress {
private:
  int age;

public:
  char name[255];
  Actress(char *name, int age):age(age) {
    strcpy(this->name, name);
  }
};
```

```cpp
int main() {
  Actress actress("Alice", 25);

  cout << actress.name << endl; //  allowed
  cout << actress.age << endl;  //  NOT allowed

  //  this is legal but ill-logical
  //  the name of an actress object should NOT
  //  be modified from outside
  strcpy(actress.name, "Eve");  //  allowed

  return 0;
}
```

Access Specifier (cont'd)

```
class Actress {
private:

  int age;

public:
  char name[255];
  Actress(char *name, int age):age(age) {
    strcpy(this->name, name);
  }



};
```

- We want actress name to be *read-only from outside*

Access Specifier (cont'd)

```
class Actress {
private:
  char name[255];
  int age;

public:
  ~~char name[255];~~
  Actress(char *name, int age):age(age) {
    strcpy(this->name, name);
  }
  char *getName() {
    return name;
  }
};
```

- We want actress name to be *read-only from outside*
- Declare name as private, and then define a public function to read it from outside

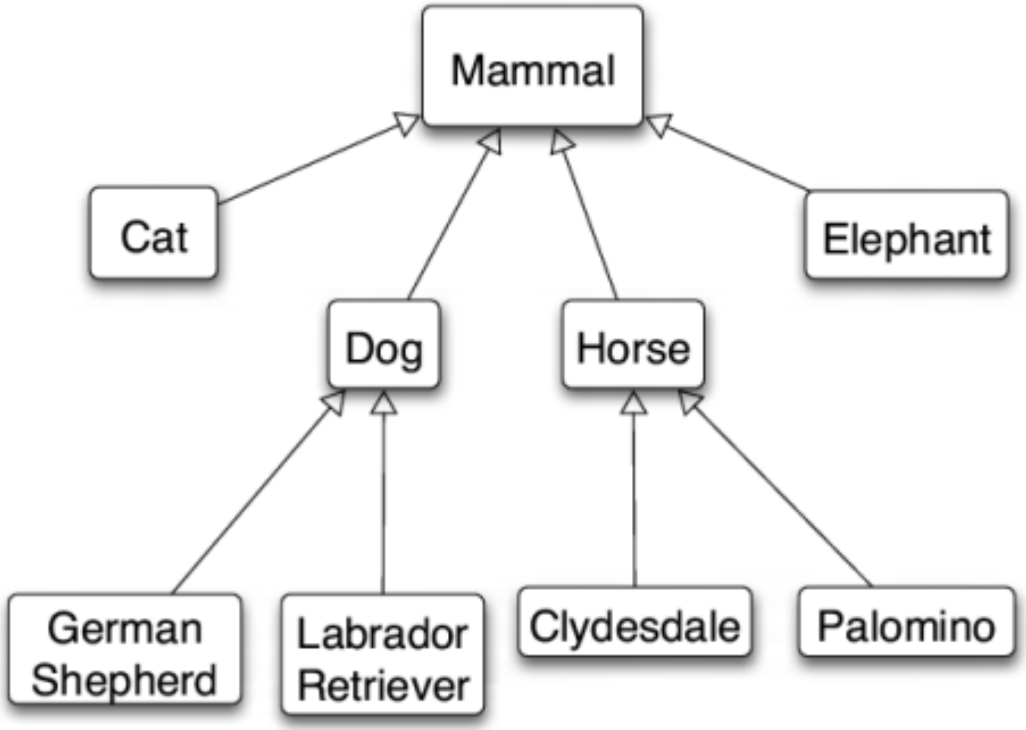
Access Specifier (cont'd)

- A common design of OOP is data encapsulation, which is to
  - define all member variables as private
  - provide enough get and set functions to read and write member variables
  - only functions that need to interact with the outside can be made public
  - supporting functions used by the member functions should also be made private

What is Inheritance

- **is-a relationship**: A hierarchical connection where one category can be treated as a specialized version of another.
    - every rectangle *is a* shape
    - every lion *is an* animal
    - every lawyer *is an* employee

- **class hierarchy**: A set of data types connected by is-a relationships that **can share common code**.
    - **Re-use**



Basic Concepts

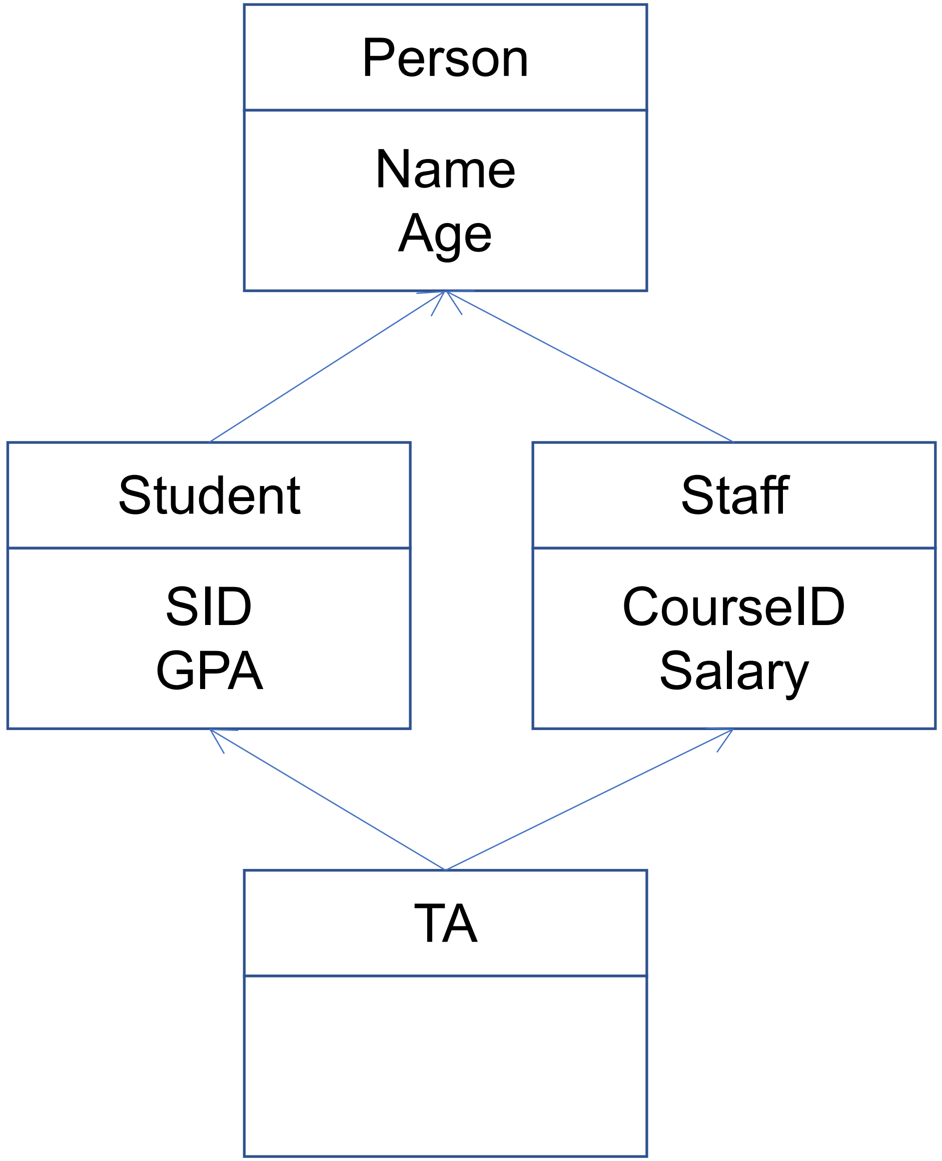
- **Inheritance**: A way to create new classes by extending existing classes

- **Base class**: Parent class that is being extended

- **Derived class**: Child class that inherits from base class(es)
    - A derived class gets a copy of every fields and methods from base class(es).
        - Note: gets a copy does NOT mean can access (details later)
    - A derived class can add its own behavior, and/or change inherited behavior

Basic Concepts

- Multiple inheritance: When one derived class has multiple base classes
- Forbidden in many object-oriented languages (e.g. Java) but allowed in C++.
- Convenient because it allows code sharing from multiple sources.
- Can be confusing or buggy, e.g. when both base classes define a member with the same name.



Syntax

```
class Parent { … };
class Child : AccessSpecifier Parent { … };


class ParentA { … };
class ParentB { … };
class Child : AccessSpecifier ParentA, AccessSpecifier ParentB { … };


For example:
class TA : public Student, public Staff { … };
```

Inheritance and Access

How inherited base class members appear in derived class

Base class members

```
class Parent {
  private:   x;
  protected: y;
  public:    z;
};
```

class Child : public Parent {…}

```
class Child {
  // x is inaccessible
  protected: y;
  public:    z;
};
```

class Child : protected Parent {…}

```
class Child {
  // x is inaccessible
  protected: y;
  protected: z;
};
```

class Child : private Parent {…}

```
class Child {
  // x is inaccessible
  private:   y;
  private:   z;
};
```

Public Inheritance: Example

```
class A {
private:
    int x;
protected:
    int y;
public:
    int z;
};
```

```
class B : public A {
public:
    void print() {
        cout << z;  // allowed
        y = 0;      // allowed
        cout << x;  // NOT allowed
    }
};
int main() {
    B obj;
    obj.y = 0;     // NOT allowed, y is protected in B
    obj.z = 0;     // allowed, z is public in B
    obj.print();   // allowed, print is public in B
    return 0;
}
```

Protected Inheritance: Example

```cpp
class A {
private:
    int x;
protected:
    int y;
public:
    int z;
};
```

```cpp
class B : protected A {
public:
    void print() {
        cout << z;  //  allowed
        y = 0;      //  allowed
        cout << x;  //  NOT allowed
    }
};
int main() {
    B obj;
    obj.y = 0;     //  NOT allowed, y is protected in B
    obj.z = 0;     //  NOT allowed, z is protected in B
    obj.print();   //  allowed, print is public in B
    return 0;
}
```

Private Inheritance: Example

```
class A {
private:
    int x;
protected:
    int y;
public:
    int z;
};
```

```
class B : private A {
public:
    void print() {
        cout << z;  // allowed
        y = 0;      // allowed
        cout << x;  // NOT allowed
    }
};
int main() {
    B obj;
    obj.y = 0;     // NOT allowed, y is private in B
    obj.z = 0;     // NOT allowed, z is private in B
    obj.print();  // allowed, print is public in B
    return 0;
}
```

Constructors in Inheritance

- Derived classes can have their own constructors

- When an object of a derived class is created, the base class's *default constructor* is executed first *at the beginning* of derived class's constructor, followed by executing the body of the derived class's constructor

```
class A {
public:
   A() { cout << "A's default constructor\n"; }
};
class B : public A {
public:
   B() {
      cout << "B's constructor\n";
   }
};
int main() {
   B b;
}
```

Constructors in Inheritance

- Derived classes can have their own constructors
- When an object of a derived class is created, the base class's *default constructor* is executed first *at the beginning* of derived class's constructor, followed by executing the body of the derived class's constructor

```
class A {
public:
   A() { cout << "A's default constructor\n"; }
   A(int a) {
      cout << "A's non-default constructor\n";
   }
};
class B : public A {
public:
   B() {
      cout << "calling A(2311) in B()\n"; A(2311);
      cout << "calling A() in B()\n";     A();
      cout << "B's constructor\n";
   }
};
int main() {
   B b;
}
```

Passing Arguments to Constructors

```
class Student {
protected:
    int sid;
public:
    Student(int sid=0) : sid(sid) {}
    int getSid() { return sid; }
};
class TA: public Student {
protected:
    int courseid;
public:
    TA(int courseid =0) : courseid(courseid) {}
    int getCourseid() { return courseid; }
};
```

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

int main() {
    Student alice(12345);
    cout << alice.getSid() << endl;

    TA bob(2311);
    cout << bob.getSid() << ": ";
    cout << bob.getCourseid() << endl;

    return 0;
}
```

*How to pass parameters to **base** constructor?*

Passing Arguments to Constructors

- To pass arguments from child constructor to parent constructor
  - augment the parameter list of child constructor to include parent constructor parameters, and
  - call parent constructor in initial list

```
class B: public A {
public:
  B(B constructor parameters + A constructor parameters) : A(A constructor's args), … {
    …
  }
};
```

Passing Arguments to Constructors

```
class Student {
protected: int sid;
public:    Student(int sid=0) : sid(sid) {}
           int getSid() { return sid; }
};
class TA: public Student {
protected: int courseid;
public:    TA(int sid=0, int courseid=0) : Student(sid), courseid(courseid) {}
           int getCourseid() { return courseid; }
};
int main() {
    int sid=12345, courseid=2311;
    TA bob(sid, courseid);
    cout << bob.getSid() << ": " << bob.getCourseid() << endl;
    return 0;
}
```

Destructors in Inheritance

- Derived classes can have their own destructors

- When an object of a derived class is destroyed, the derived class's destructor is executed first, followed by the base class's destructor

```
class A {
public:
    ~A() { cout << "A's destructor\n"; }
};
class B : public A {
public:
    ~B() { cout << "B's destructor\n"; }
};
int main() {
    B b = new B();
    delete b;
    return 0;
}
```

Outline

- Access specifier: public, protect, and private
- Inheritance
- Operator overloading
- Polymorphism

Operator Overloading

- Enabling C++'s operators to work with class objects
- Using traditional operators with user-defined objects
- Examples of already overloaded operators
  - Operator << is both the stream-insertion operator and the bitwise left-shift operator
  - **+** and **-**, perform arithmetic on multiple types

```
int a = 1;
int b = 2;
if (a < b)
    cout << "a < b " << endl;
```

```
class Triangle { ... };
Triangle a, b;
...
if (a < b) // errors without overloading
    cout << "a < b " << endl;
```

Operator Overloading

```
class Triangle {
private:
    double s1, s2, s3;
    double area;
public:
    Triangle() {}
    void setSides();
    void computeArea();
    double getArea();
};
```

```
Triangle a, b;

a.setSides();
b.setSides();
```

lhs = Left Hand Side

rhs = Right Hand Side

```
if (a < b) {
    cout << "Triangle a is smaller than triangle b\n";
}
```

Operator Overloading

+ - * / % ^ & | ~ ! , = < > <= >=

++ -- << >> == != && || += -= *= /=

%= ^= &= |= <<= >>= [] () ->

->* new new[] delete delete[]

Operator Overloading

- Overloading an operator
  - Write function definition as normal
  - Function name is keyword **operator** followed by the symbol for the operator being overloaded
    - **operator+** used to overload the addition operator (**+**)
- Special operators
  - To use an operator on a class object it must be overloaded except the assignment operator**(=)** or the address operator**(&)**
    - Assignment operator by default performs member-wise assignment
    - Address operator (&) by default returns the address of an object

Operator Overloading: Member Function

- Add a function called operator _ (e.g., <, +, !) to your class:

```
class Circle {
private:
    int radius;
public:
    Circle(int radius): radius(radius) {};
    bool operator< (Circle& rhs);
    //  lhs (left hand side) of operator < is this.
};

bool Circle::operator<(Circle& rhs) {
    if (radius < rhs.radius) return true;
    else return false;
}
```

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

int main() {
    Circle a(3);
    Circle b(5);
    cout << (a < b);
    return 0;
}

// a < b ←→ a.operator<(b)
```

Operator Overloading: Friend Function

- *Friend function:* a special function which is a non-member function of a class but has privilege to access private and protected data of that class

- Friend function can be declared in any section of the class i.e. public or private or protected

- When friend function is called, neither name of object nor dot operator is used

Operator Overloading: Friend Function

```
class Triangle {
private:
    double s1, s2, s3;
public:
    Triangle() { s1=0; s2=0; s3=0; }
    Triangle(double s1, double s2, double s3): s1(s1), s2(s2), s3(s3) {}
    double getArea();
    friend bool operator< (Triangle &lhs, Triangle &rhs);
    friend bool operator> (Triangle &lhs, Triangle &rhs);
    friend ostream& operator<< (ostream &outs, Triangle &c);
};
double Triangle::getArea() {
    double s = (s1+s2+s3)/2;
    return sqrt(s*(s-s1)*(s-s2)*(s-s3));
}
```

Operator Overloading: Friend Function

```cpp
bool operator<(Triangle &lhs, Triangle &rhs) {
    return lhs.getArea() < rhs.getArea();
}

bool operator>(Triangle &lhs, Triangle &rhs) {
    return lhs.getArea() > rhs.getArea();
}

ostream &operator << (ostream &outs, Triangle &t) {
    outs << "The sides are: ";
    outs << t.s1 << " " << t.s2 << " " << t.s3 << " ";
    outs << "The area is: ";
    outs << t.getArea() << endl;
    return outs;
}
```

```cpp
int main() {
    Triangle t1(3, 4, 5);
    Triangle t2(5, 6, 7);
    cout << t1;
    cout << t2;
    if (t1 < t2) {
        cout << "t1 is smaller\n";
    } else {
        cout << "t2 is smaller\n";
    }
    return 0;
}
```

Outline

- Access specifier: public, protect, and private
- Inheritance
- Operator overloading
- Polymorphism

Type Casting in Class Inheritance

```
class Animal {
    …
};
class Human : public Animal {
    …
};
// Only down-casting is allowed in class type conversion
// You can say a human is an animal, but not vice versa
Animal *a = new Human();      // legal
Human *b = new Animal();      // illegal
```

Static Type vs Dynamic Type

- *Static type*: the declared type
- *Dynamic type*: the actual type assigned

```cpp
class Animal {
    …
};

class Human : public Animal {
    …
};

class Dog : public Animal {
    …
};
```

```cpp
int main() {
  Human *human = new Human();
  Dog *dog = new Dog();

  Animal *a;     //  the static type of a is Animal
  a = human;     //  the dynamic type of a is Human
  a = dog;       //  the dynamic type of a is Dog

  delete human;
  delete dog;
  return 0;
}
```

Override

- To re-implement a base class's member function by writing a new version of that function (with the same function prototype) in a derived class

```
class Shape {
public:
    void print() { cout << "I am a shape\n"; }
};
class Circle: public Shape {
private:
    double radius;
public:
    Circle(double radius_):radius(radius_) {};
    void print() { cout << "I am a circle and my radius is " << radius << "\n"; }
};
```

Override vs Overload

- Overload

```
double sum(double, double, double);
double sum(double, double);
```

- Override

```
void Animal::makeSound();
void Human::makeSound();
void Dog::makeSound();
```

Polymorphism

- Polymorphism means "many forms"
- In inherited classes, the same function behaves differently depending on types

```
void Animal::makeSound();
void Human::makeSound();
void Duck::makeSound();
void Dog::makeSound();
void Cat::makeSound();
```

Polymorphism: Static Binding

- The called function is determined by *static type*

```
class Animal {
  public:
  void sayHi() {
    cout << "…\n";
  }
};
```


```
class Human : public Animal {
  public:
  void sayHi() {
    cout << "hi\n";
  }
};
```

```
class Dog : public Animal {
  public:
  void sayHi() {
    cout << "wow wow\n";
  }
};
```

```
int main() {
  Human *human = new Human();
  Dog *dog = new Dog();
  Animal *a;

  //  the static type of a is Animal
  a = human;
  a->sayHi();  // will print "…"
  a = dog;
  a->sayHi();  // will print "…"

  delete human;
  delete dog;
  return 0;
}
```

Polymorphism: Dynamic Binding

- We want the called function to be determined by *dynamic type*

```
int main() {
  Human *human = new Human();
  Dog *dog = new Dog();

  Animal *a;             //  the static type of a is Animal
  a = human;             //  the dynamic type of a is Human
  a->sayHi();            //  we want it to print "Hi"
  a = dog;               //  the dynamic type of a is Dog
  a->sayHi();            //  we want it to print "wow wow"

  delete human;
  delete dog;
  return 0;
}
```

Dynamic Binding: Virtual Function

- A *virtual function* is declared in the base class using the keyword virtual and is re-defined (Overridden) in the derived class

- Virtual functions are Dynamic in nature

- Allows dynamic binding at runtime

Polymorphism: Dynamic Binding

```cpp
class Base {
public:
  virtual void print() {
    cout << "print base\n";
  }
  void show() {
    cout << "show base\n";
  }
};
```

```cpp
class Derived : public Base {
public:
void print() {
    cout << "print derived\n";
  }
  void show() {
    cout << "show derived\n";
  }
};
```

```cpp
int main() {
  Base *base;
  Derived *derived = new Derived();

  base = derived;
  base->print(); //  dynamic binding
                 //  will print "print derived"

  base->show();  //  static binding
                 //  will print "show base"

  delete derived;
  return 0;
}
```

Outline for Lec1 Introduction

- What’s a computer
  - Numbering system
  - Logic gates and circuits
  - Stored Program Computer and ISA
- Programming languages
  - Machine/ Symbolic/High-level Language
  - Compiler
- Basics of computer programming
  - Logic Flow
  - Developing: Coding / Compilation/ Linking
  - C++ Syntax: Function/Statement/…

Outline for Lec2 Data, Operators, and BasicIO

- C++ basic syntax
- Variable and constant
- Operators
- Basic I/O

Outline for Lec3 Control Flow - Condition

- Logical data type, operators and expressions
- If statement
  - Simple
  - Nested
- Switch statement

Outline for Lec4 Control Flow - Loop

- Loop
  - while
  - do-while
  - for
- Programming styles for control flow

Outline for Lec5 Function

- Defining a function
- Calling a function
- Declare a function (function prototype)
- Passing parameters
- Recursive functions

Outline for Lec6 Array

- Array definition
- Array initialization
- Passing array to functions
- Array operations
- Multi-dimensional array

Outline for Lec7 String

- *char* recap
- C string basics
- Reading and printing C strings
- Common string functions
- Safety of string functions
- File I/O (Lec8)

Outline for Lec9 Pointer I

- Recap: variable and memory
- Pointer and its operations
- Pass by pointer
- Array and pointer

Outline for Lec10 Pointer II

- Pointer arithmetic
- Pointer array vs Array pointer
- Pointer of pointer & Pointer reference
- Dynamic memory allocation

Outline for Lec11 & 12

- Prerequisite: C-like struct and overload
- Class and objects: basic concepts and syntax
- Constructors and destructors
- Access specifier: public, protect, and private
- Inheritance
- Operator overloading
- Polymorphism