CS2313 Computer Programming

LT8 – Class

Questions & Discussions

- The video has briefly introduced class and object in C++ programming. Please discuss the following questions with your team members.
  - A member function can access the data in _____ ,
    A. the class of which it is member
    B. the public part of its class only
    C. the private part of its class only
    D. None of above
  - What is a class? How does it accomplish data hiding?

Outline

- Defining classes
- Defining member functions & scope resolution operator
- Public & private members
- Accessors
- Constructors
- Friend functions
- Const modifier
- Operator overloading

Class and Object

- Class and object are important features of Object-oriented Programming Language (C++, Java, C#)
- With class, variables and their directly related functions can be grouped together to form a new data type
- It promotes reusability and object-oriented design (not covered in this course)
- Object is an instance of class, i.e. *class* is a blue-print and its product is its *object*.

Class and Object : Example

Without class/object

```
int radius;
int width, height;

double getCircleArea(){
   return  3.14*radius*radius;
}
double getRectangleArea(){
   return  width*height;
}
double getCirclePerimeter(){
   return  2*3.14*radius;
}
double getRectanglePerimeter(){
   return  2*(width+height);
}
```

With class/object

```
class Circle {
   public:
   int radius;
   double getArea(){
          return 3.14*radius*radius;
   }
   double getPerimeter(){
          return 2*3.14*radius;
   }
}
class Rect{
   public:
   int width, height;
   double getArea(){
          return   width*height;
   }
   double getPerimeter(){
          return   2*(width+height);
   }
}
```

Class and Object

```
void main(){
   cout << "Please enter the radius of circle";
   cin >> radius;
   cout << getCircleArea();

   cout << "Please enter the width and height of a rectangle";
   cin >> width >> height;
   cout << getRectangleArea();
}
```

Without class/object

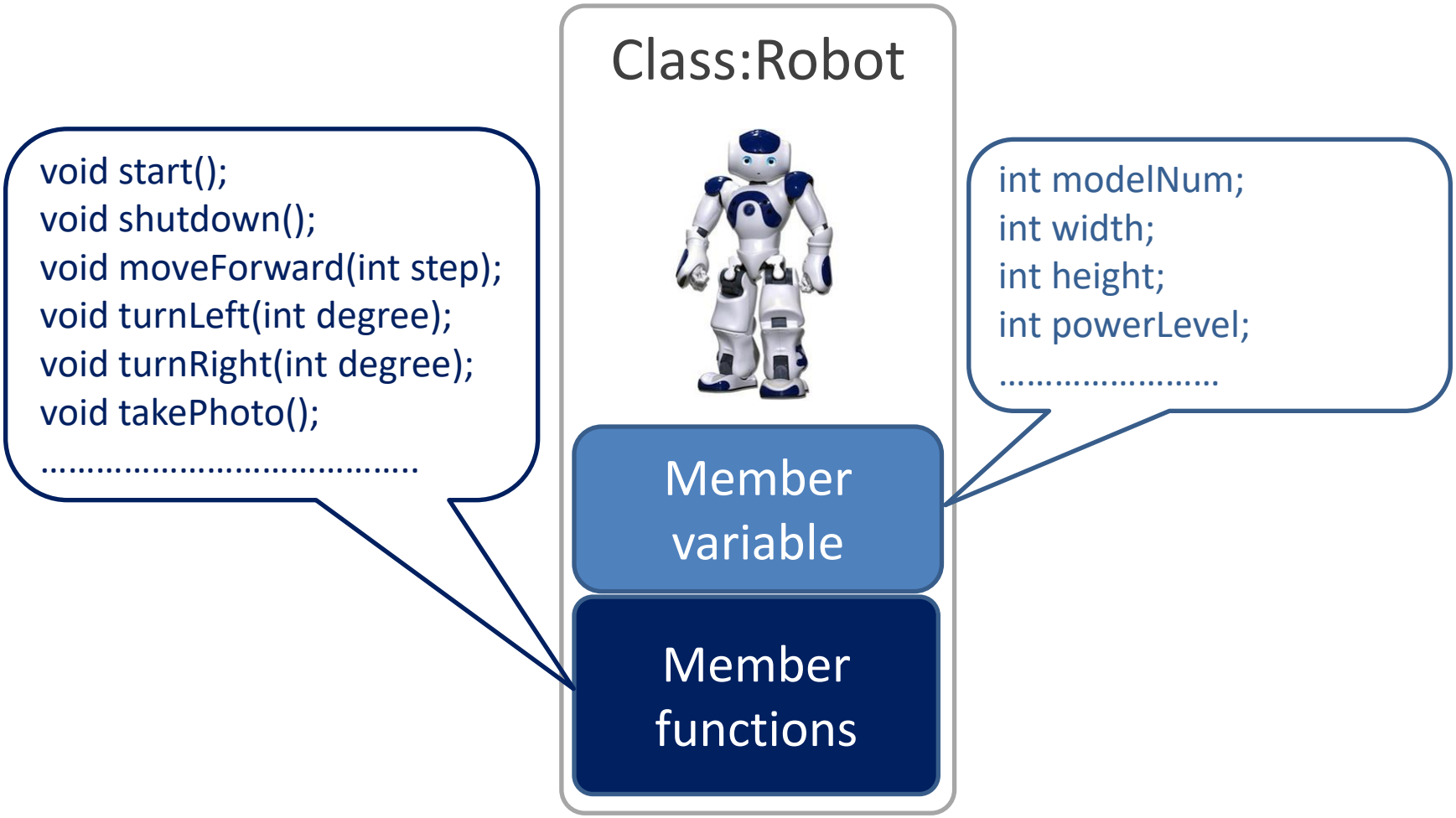
```
void main(){
   Rect r;                    //Rect is a class, r is an object of Rect
   Circle c;
   cout << "Please enter the radius of circle";
   cin >> c.radius;
   cout << c.getArea();

   cout << "Please enter the width and height of a rectangle";
   cin >> r.width >> r.height;
   cout << r.getArea();
}
```

With class/object

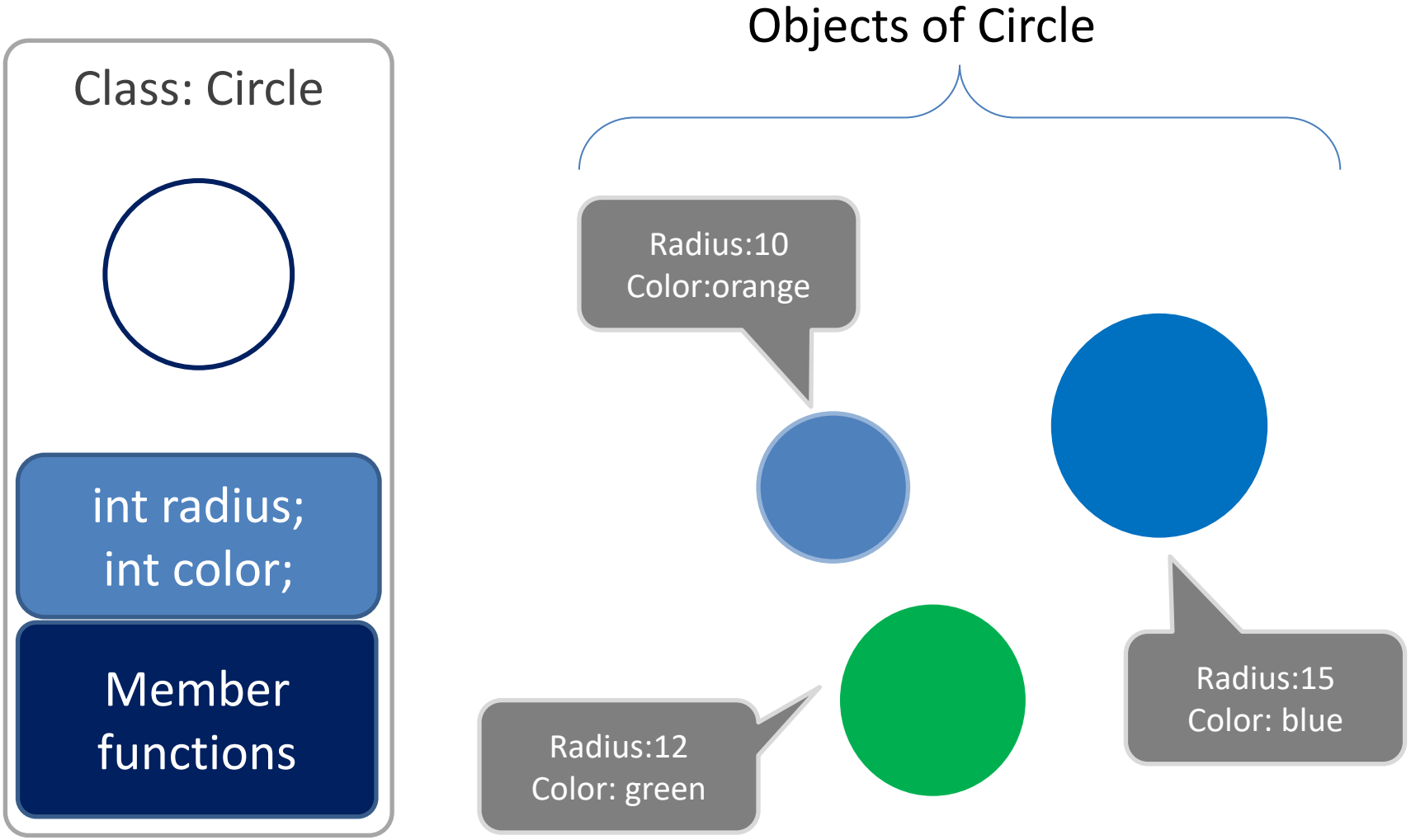
Class in Computer Programming

- An abstract view of real-world objects, e.g. car, horse
- Computer program is a model of real-world problem
- Simple problem: program with variables and functions
- Large scale program: class and object
- Class:
  - definition of program component
  - consists of member variables and member functions
  - Member variable : variable belong to class
  - Member function: function primary designed to access/manipulate the member variable of the class
- Object:
  - An instance of class / runtime representation of a class

Class in programming



What is an object?



Classes and Objects in C++

- A class is a data type, objects are variables of this type
- An object is a variable with member functions and data values
- `cin`, `cout` are objects defined in header `<iostream>`
- C++ has great facilities for you to define your own class and objects

Defining classes

```
class class_name {
    public / protected / private:
    attribute1 declaration;
    attribute2 declaration;
    method1 declaration;
    method2 prototype;
};
return_value classname::method2{
    method body statement;
}
```

Defining classes (example I)

```
#include <iostream>
using namespace std;
class DayOfYear
{
   public:
     int month;
     int day;
     void output(){
       cout << "month = " << month;
       cout << ", day = " << day << endl;
      }
};
```

Member variables

Member method/function

Member function

- In C++, a class definition commonly contains only the prototypes of its member functions (except for *inline functions*)
- Use *classname::functionName* to define the member function (method) of particular class.

```
class Circle
{
  ……
  int radius;
  ……
  double getArea();
};
double Circle::getArea(){
  return 3.1415*radius*radius;
}
```

Defining classes (example II)

```
#include <iostream>
using namespace std;
class DayOfYear
{
public:
  void output(); //member func. prototype
  int month;
  int day;
};
void DayOfYear::output()
{
  cout << "month =" << month
       << ", day =" << day << endl;
}
```

Define the method elsewhere

Create object, access its function

- To declare an object of a class

  Class_name variable_name;

Examples:

```
Circle c1,c2;
DayofYear today;
```

- A member function of an object is called using the dot operator:
  - `today.output();`
  - `c1.getArea();`

Main function

```
void main()
{
  DayofYear today, birthday;
  cin >> today.month >> today.day;
  cin >> birthday.month >> birthday.day;
  cout << "Today's date is: ";
  today.output();
  cout << "Your birthday is: ";
  birthday.output();
  if (today.month == birthday.month
       && today.day == birthday.day)
       cout << "Happy Birthday!\n";
}
```

Public and private members

- By default, all members of a class are private
- You can declare public members using the keyword `public`
- Private members can be accessed only by member functions (and *friend* functions) of that class, i.e. only from within the class, not from outside

A new class definition for DayOfYear

```
class DayOfYear
{
public:
  void input();
  void output();
  void set(int new_m, int new_d);

  int get_month();
  int get_day();
private:
  bool valid(int m, int d); // check if m,d valid
  int month;
  int day;
};
```

Member function definitions

```
bool DayOfYear::valid(int m, int d)
{
  if (m<1 || m>12 || d<1) return false;
  switch(m){
    case 1: case 3: case 5: case 7:
    case 8: case 10: case 12:
         return d<=31; break;
    case 4: case 6: case 9: case 11:
         return d<=30; break;
    case 2:
         return d<=29; break;
    }
}
```

Member function definitions

```
void DayOfYear::input()
{
  int m, d;

  // input and validate
  do {
    cout << "Enter month and day as numbers: ";
    cin >> m >> d;  // local var. of input()
  } while (!valid(m,d));

  month = m;  // accessing private members
  day = d;
}
```

Member function definitions

```
void DayOfYear::set(int new_m, int new_d)
{
  if (valid(new_m, new_d)) {
     month = new_m;
     day   = mew_d;
  }
}

int DayOfYear::get_month()
{  return month;
}

int DayOfYear::get_day()
{  return day;
}
```

A new main program

```
void main()
{
  DayOfYear today, birthday;

  today.input();
  birthday.input();
  cout << "Today's date is:\n";
  today.output();
  cout << "Your birthday is:\n";
  birthday.output();

  if (today.get_month()==birthday.get_month()
                          &&
      today.get_day() == birthday.get_day())
    cout << "Happy Birthday!\n";
}
```

Discussion Questions

- Can we use the same function name for a member function of a class and an outside function in the same program file? If yes, how are they distinguished? If no, give reasons.

Private Variables and Access functions

- Member functions that give you access to the values of the private member variables are called *access functions*, e.g., `get_month`, `set`
- Useful for controlling access to private members:
  - E.g. Provide data validation to ensure data integrity.
- Needed when testing equality of 2 objects. (The predefined equality operator = = does not work for objects and variables of structure type.), e.g. obj1==obj2 (not work!)

Why private variable?

- Prevent others from accessing the variables directly, i.e. variables can be only accessed by access functions.

```
class DayOfYear
{
  ……
  private:
       int month;
       int day;
  ……
};
```

```
void DayOfYear::set(int new_m, int
   new_d)
{
   ……
      month = new_m;
      day   = mew_d;
   ……
}
int DayOfYear::get_month()
{
   return month;
}

int DayOfYear::get_day()
{
   return day;
}
```

Why private variables?

- Change of the internal presentation, e.g. variable name, type, will not affect the how the others access the object. Caller still calls the same function with same parameters

```
class DayOfYear
{
  ……
  private:
       int m;
       int d;
  ……
};
```

```
void DayOfYear::set(int new_m, int new_d)
{
   ……
      m = new_m;
      d = mew_d;
   ……
}
int DayOfYear::get_month()
{
   return m;
}
int DayOfYear::get_day()
{
   return d;
}
```

Why private members?

- The common style of class definitions
  - To have all member variables private
  - Provide enough access functions to get and set the member variables
  - Supporting functions used by the member functions should also be made private
  - Only functions that need to interact with the outside can be made public

Assignment operator for objects

- It is legal to use assignment operator = with objects or with structures
- E.g.
```
DayOfYear due_date, tomorrow;
    tomorrow.input();
    due_date = tomorrow;
```
- This effectively makes both variables pointing to the same memory address of the object

Constructors for initialization

- Class contains variables and functions
- Variables should be initialized before use in many cases
- In C++, a constructor is designed to initialize variables
- A *constructor* is a member function that is automatically called when an object of that class is declared
- Special rules:
  - A constructor must have the same name as the class
  - A constructor definition cannot return a value

Example: Bank account

- E.g., Suppose we want to define a bank account class which has member variables `balance` and `interest_rate`. We want to have a constructor that initializes the member variables.

```
class BankAcc
{
public:
  BankAcc(int dollars, int cents, double rate);
  ...
private:
  double balance;
  double interest_rate;
};
...
BankAcc::BankAcc(int dollars, int cents, double rate)
{
    balance = dollars + 0.01*cents;
   interest_rate = rate;
}
```

Constructors

- When declaring `BankAcc` objects:

```
BankAcc account1(10,50,2.0),
        account2(500,0,4.5);
```

- Note: A constructor cannot be called in the same way as an ordinary member function is called:

```
account1.BankAcc(10,20,1.0); // illegal
```

Constructors

- More than one versions of constructors are usually defined (overloaded) so that objects can be initialized in more than one way, e.g.

```
class BankAcc
{
public:
  BankAcc(int dollars, int cents, double rate);
  BankAcc(int dollars, double rate);
  BankAcc();
  ...
private:
  double balance;
  double interest_rate;
};
```

Constructors

```
BankAcc::BankAcc(int dollars, int cents, double rate)
{
   balance = dollars + 0.01*cents;
   interest_rate = rate;
}
BankAcc::BankAcc(int dollars, double rate)
{
   balance = dollars;
  interest_rate = rate;
}
BankAcc::BankAcc()
{
   balance = 0;
  interest_rate = 0.0;
}
```

Constructors

- When the constructor has no arguments, don't include any parentheses in the object declaration.
- E.g.

```
BankAcc acc1(100, 50, 2.0), // OK
        acc2(100, 2.3),     // OK
        acc3(),           // error
        acc4;           // correct
```

- The compiler thinks that it is the prototype of a function called `acc3` that takes no arguments and returns a value of type `BankAcc`

Constructors

- Alternative way to call a constructor:

  obj = constr_name(*arguments*);

  E.g., `BankAcc account1;`
  `account1 = BankAcc(200, 3.5);`

- Mechanism: calling the constructor creates an anonymous object with new values; the object is then assigned to the named object

- A constructor behaves like a function that returns an object of its class type

Default constructor

- A constructor with no parameters
- Will be called when no argument is given

```
class Circle{
  int radius;
  Circle();
  double getArea();
};
void Circle::Circle(){
  radius=0;
}
double Circle::getArea(){
  return 3.1415*radius;
}
```

```
void main(){
  Circle circle;
  circle.getArea();
}
```

Default constructors

- A default constructor will be generated by compiler automatically if NO constructor is defined.
- However, if any non-default constructor is defined, calling the default constructor will have compilation error.

```
class Circle{
   int radius;
   Circle(int r);
   double getArea();
};
Circle::Circle(int r){
   radius=r;
}
double Circle::getArea(){
   return 3.1415*radius;
}
```

```
void main(){
   Circle circle; //illegal
   Circle circle(6); //OK
   circle.getArea();
}
```

Discussion Questions

- Can you list some special properties of the constructor functions?
- Suppose we have a class with overloaded constructors as follows.
  - Which constructor is called when **one int** type argument is given?
  - Which constructor is called when **one float** type argument is given?
  - Which constructor is called when **two** arguments (**one int, one float**) is given?

```
class C {
   private:
          int p;
          float r;
   public:
          C(int x){p=x;}
          C(int x, float y) {p=x; r=y;}
          C(float y){r=y;}

};
```

Friend Function

- Not all functions could logically belong to a class, and sometimes, it is more natural to implement an operation as ordinary (non-member) functions.
- e.g. Equality (==) function that test if 2 objects are equal
- Equality operator = = cannot be applied directly on objects or structures
- Defining it as a member function will lose the symmetry
- It is more natural to define such a function as an ordinary (nonmember) function

Equality testing: ordinary function

```
#include <iostream>
using namespace std;
class Rectangle
{
public:
   Rectangle(int w,int h);
   int getArea();
   int getWidth();
   int getHeight();
private:
  int width;
  int height;
};
```

```
Rectangle::Rectangle(int w,int h){
   width=w;
   height=h;
}
int Rectangle::getWidth(){
   return width;
}
int Rectangle::getHeight(){
   return height;
}
int Rectangle::getArea(){
   return width*height;
}
```

Equality testing: ordinary function

```
bool equal(Rectangle r1, Rectangle r2){
  if (r1.getWidth()==r2.getWidth() &&
      r1.getHeight()==r2.getHeight())
      return true;
  else
      return false;
}
int main()
{
  Rectangle ra(10,22), rb(10,21);
  if ( equal(ra, rb) )
    cout << "They are the same\n");
  return 0;
}
```

Friend function

- The previous equality function needs to call access functions several times $\Rightarrow$ not efficient
- However, declaring the member variable as public and directly accessing them are not recommended

```
class Rectangle {
 public:
 int width,height;
……
}

bool equal(Rectangle r1, Rectangle r2){
if (r1.width ==r2.width && r1.height==r2.height)
 return true;
else
 return false;
}
```

Friend function

- Solution: Define a friend function!
- A friend function of a class is *not* a member function of the class but has access to the private members of that class
- A friend function doesn't need to call access functions → more efficient
- Also the code looks simpler
- A friend function will be public no matter it is defined under "public:" or not

Equality testing: friend function

```
#include <iostream>
using namespace std;
class Rectangle
{
public:
   Rectangle(int w,int h);
   friend bool equal(Rectangle
   r1,Rectangle r2);
   int getArea();
   int getWidth();
   int getHeight();

private:
  int width;
  int height;
};
```

```
Rectangle::Rectangle(int
  w,int h){
  width=w;
  height=h;
}
int Rectangle::getWidth(){
  return width;
}
int Rectangle::getHeight(){
  return height;
}
```

Equality testing: friend function

```
/*Note the friend function is not implemented in Rectangle
   class*/

bool equal(Rectangle r1, Rectangle r2){
   if (r1.width ==r2.width && r1.height==r2.height)
       return true;
   else
       return false;
}

int main()
{
    Rectangle ra(10,22), rb(10,21);
    if ( equal(ra, rb) )
        cout << "They are the same\n");
    return 0;
}
```

`const` modifier revisited

- By default, parameters passed to a function could be call-by-value or call-by-reference mechanism
- Call-by-value: a copy of variable is passed.
- Call-by-reference: the original data, not the copy is passed to a function
- In call-by-reference, if the function is not supposed to change the value of the parameter, you can mark it with a const modifier
- The compiler will then complain when you modify it by mistake

`const` modifier revisited

- Call-by-reference:
  - the original data, not the copy is passed to a function
  - Add '&' before the parameter name in function prototype and definition.

```
class Rectangle
{ ……
  friend bool equal(Rectangle &r1,Rectangle &r2);
  ……
};
bool equal(Rectangle &r1, Rectangle &r2){
  if (r1.width ==r2.width && r1.height==r2.height)
  ……
}
```

const parameter modifier

```
class Circle
{
   int radius;
public:
   Circle(int r);
   void set(Circle &c);
   double getArea();
};
Circle::Circle(int r){
   radius=r;
}
void Circle::set(Circle &c){
   radius=c.radius;
}
double Circle::getArea(){
   return 3.14*radius*radius;
}
```

```
void main(){
  Circle c1(3);
  Circle c2(5);

  cout << c1.getArea();
  cout << '=';
  cout << c2.getArea();
  cout << endl;

  c2.set(c1);

  cout << c1.getArea();
  cout << '=';
  cout << c2.getArea();
  cout << endl;

}
```

const parameter modifier

```
class Circle
{
   int radius;
public:
   Circle(int r);
   void set(Circle &c);
   double getArea();
};
Circle::Circle(int r){
   radius=r;
}
void Circle::set(Circle &c){
   c.radius=radius;
}
double Circle::getArea(){
   return 3.14*radius*radius;
}
```

```
void main(){
  Circle c1(3);
  Circle c2(5);

  cout << c1.getArea();
  cout << '=';
  cout << c2.getArea();
  cout << endl;

  c2.set(c1);

  cout << c1.getArea();
  cout << '=';
  cout << c2.getArea();
  cout << endl;

}
```

const parameter modifier

```
class Circle
{
   int radius;
public:
   Circle(int r);
   void set(const Circle &c);
   double getArea();
};
Circle::Circle(int r){
   radius=r;
}
void Circle::set(const Circle
   &c){
   c.radius=radius;
}
double Circle::getArea(){
   return 3.14*radius*radius;
}
```

```
void main(){
   Circle c1(3);
   Circle c2(5);

   cout << c1.getArea();
   cout << '=';
   cout << c2.getArea();
   cout << endl;

   c2.set(c1);

   cout << c1.getArea();
   cout << '=';
   cout << c2.getArea();
   cout << endl;
```

Compile will complain!

Overloading operators

- An operator is really a function that is called using a different syntax for listing its arguments

- E.g.

```
x+y       +(x,y)       add(x,y)
x==y      ==(x,y)      equal(x,y)
```

- Operators can be overloaded in 2 ways:

  As a friend function

  As a member function

Overloading operators: Friend function

```
class Circle{
  int radius;
public:
  Circle(int r);
  void set(const Circle &C);
  double getArea()  const;
  int getRadiusSquare() const;
  friend Circle operator+(const Circle &c1,const Circle &c2);
};
```

```
Circle operator+(const Circle &c1,const Circle &c2){
        Circle c3(c1.radius+c2.radius);
        return c3;
}
void main(){
        Circle c1(3);
        Circle c2(5);
        Circle c3=c1+c2;
        cout << c3.getArea();
}
```

Questions for Group Discussion

- What is the output of following code?

```
class complex {
   int i;
   int j;
public:
   complex(){}
   complex(int a, int b) { i = a; j = b; }
   complex operator+(complex c) {
         complex temp;
         temp.i = i + c.i;
         temp.j = j + c.j;
         return temp; }
   void show(){
         cout<<"Complex Number: "<<i<<"  "<<j<<endl; }
};

int main(){
   complex c1(1,2);
   complex c2(3,4);
   complex c3 = c1 + c2;
   c3.show();
   return 0;
}
```