Creative Software Programming

8 – Inheritance, Const & Class

Today's Topics

- Inheritance
- Overriding
- Constructor, Destructor & Inheritance
- Multiple Inheritance
- const & Class

Fundamental Principles of Object Oriented Programming

- Encapsulation (already covered)
  - Binding the data with the code that manipulates it into a single unit (class) & hiding details of the unit (data hiding).
- Inheritance (Today's topic)
  - When a class inherits another class, it has the same behavior or characteristics of another.
- Polymorphism (Next lecture)
  - The ability to create a variable, a function, or an object that has more than one form.

Inheritance

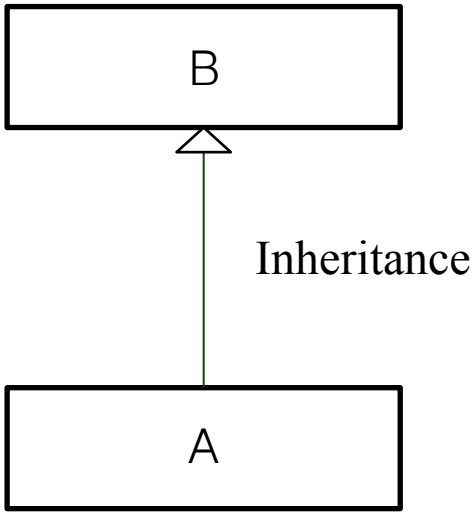
- Build a class on top of existing classes.
  - Minimize re-implementing similar functionalities.
  - Establish relations between classes/types.
  - Customized functionalities.

Inheritance: Is-a Relationship

- "Is-a" relationship: use (public) inheritance when A is a B.
  - A car is a vehicle.
    A truck is a vehicle.
    A cart is a vehicle.
    …
  - A student is a person.
    A professor is a person.
    …
  - A person is an animal.
    A dog is an animal.
    …

Inheritance

- If a class A inherits another class B,
  - Class A implicitly "has" the member variables and functions of class B.
  - Class A can have additional member variables and functions.

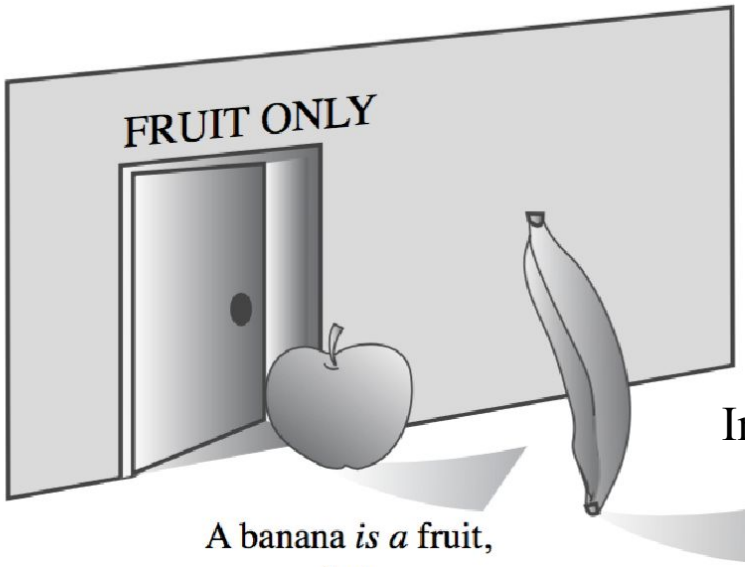


(by UML)

Base class or **Parent class** or **Super class**

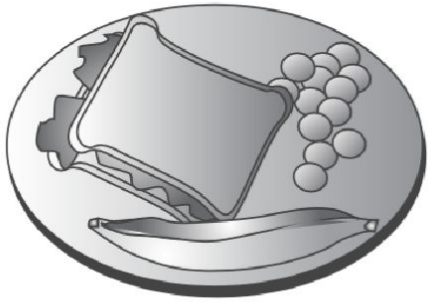
Derived class **Child class** **Subclass**

Inheritance: Is-a Relationship



Inheritance: is-a relation

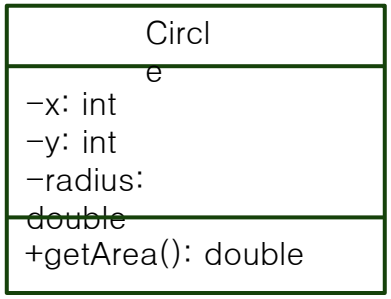
A banana *is a* fruit,
but
a lunch *has* a banana.



Composition: has-a relation

UML Class Diagram Example

Unified Modeling Language (UML): for visualize the design of a software system.



+: public
-: private
#: protected

variable: data type
method(parameter): return type

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

class Circle {

private:
    int x, y;
    double radius;
public:
    Circle(int px, int py, double pradius) {
        x=px, y=py, radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

int main()
{
    Circle c(2,3,4);
    cout << c.getArea() << endl;

}
```

An Inheritance Example

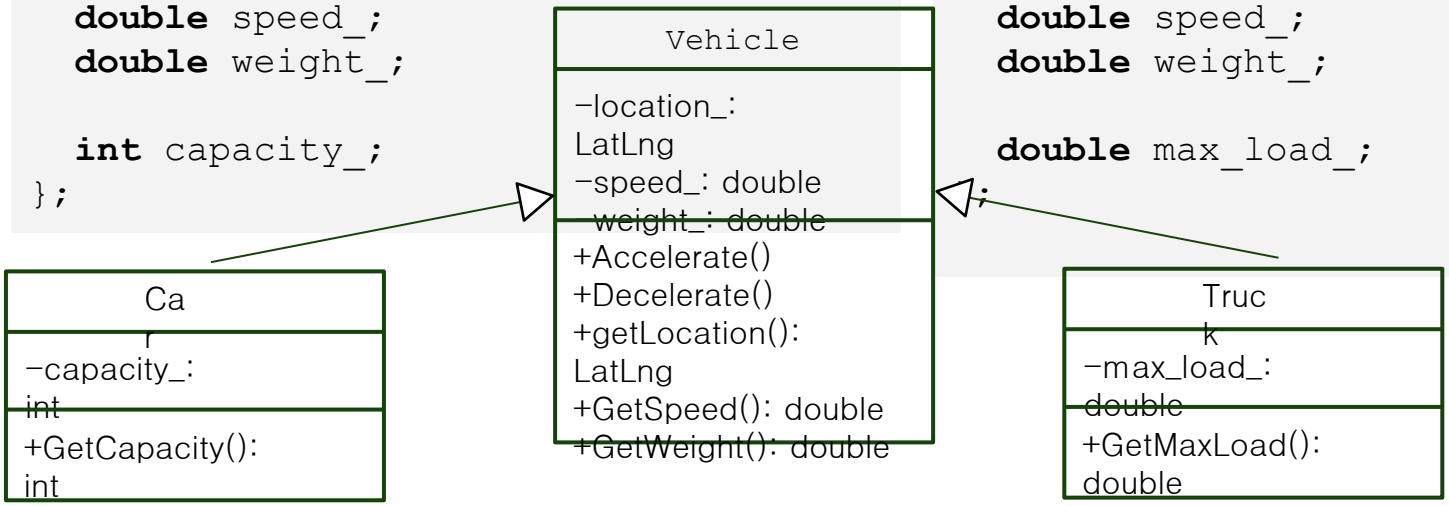
```
class Car {
 public:
  Car() {}

  void Accelerate();
  void Decelerate();
  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

  int GetCapacity();

 private:
  LatLng location_;
  double speed_;
  double weight_;

  int capacity_;
};
```

```
class Truck {
 public:
  Truck() {}

  void Accelerate();
  void Decelerate();
  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

  double GetMaxLoad();

 private:
  LatLng location_;
  double speed_;
  double weight_;

  double max_load_;
};
```

An Inheritance Example

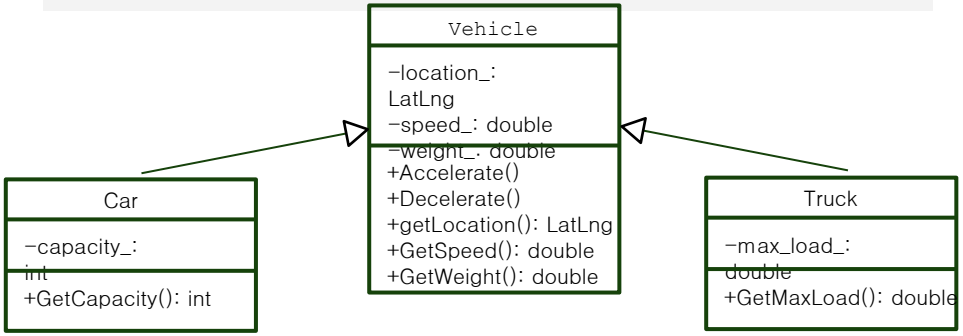
```
class Car {
 public:
  Car() {}

  void Accelerate();
  void Decelerate();
  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

  int GetCapacity();

 private:
  LatLng location_;
  double speed_;
  double weight_;

  int capacity_;
};
```

```
class Truck {
 public:
  Truck() {}

  void Accelerate();
  void Decelerate();
  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

  double GetMaxLoad();

 private:
  LatLng location_;
  double speed_;
  double weight_;

  double max_load_;
};
```



An Inheritance Example

```
// Vehicle class.

class Vehicle {
 public:
  Vehicle() {}
  void Accelerate();
  void Decelerate();

  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

 private:
  LatLng location_;
  double speed_;
  double weight_;
};
```

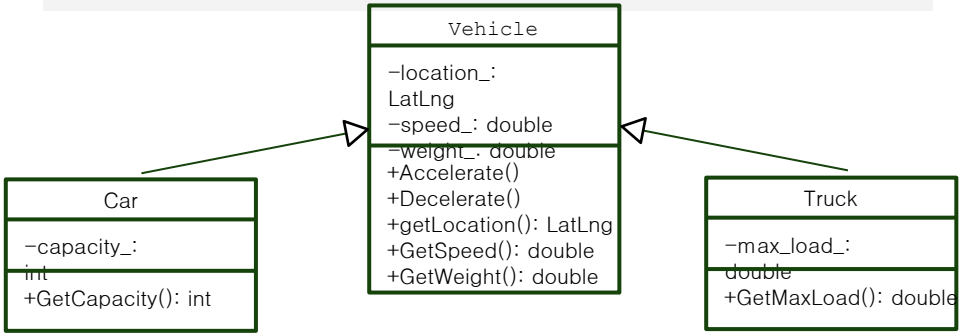



```
// Car class.

class Car : public Vehicle {
 public:
  Car() : Vehicle() {}

  int GetCapacity();

 private:
  int capacity_;
};
```

```
// Truck class.

class Truck : public Vehicle {
 public:
  Truck() : Vehicle() {}

  double GetMaxLoad();

 private:
  double max_load_;
};
```

An Inheritance Example

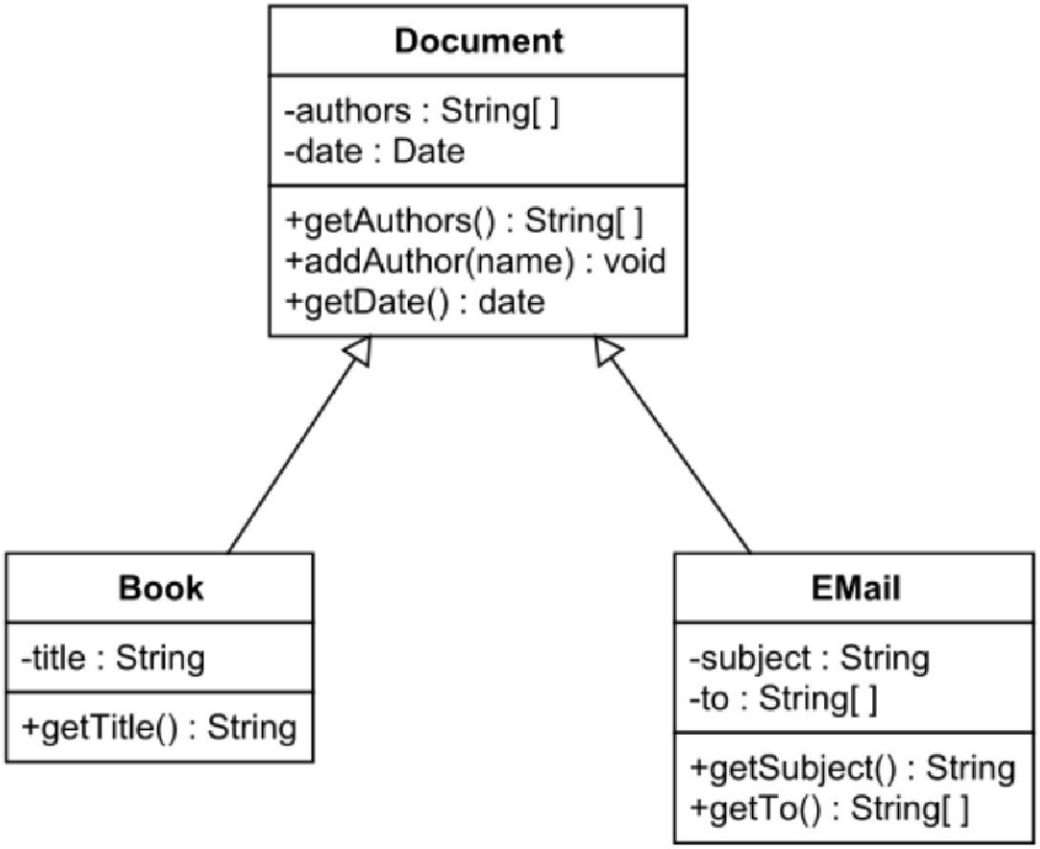
```
// Vehicle class.

class Vehicle {
 public:
  Vehicle() {}
  void Accelerate();
  void Decelerate();

  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

 private:
  LatLng location_;
  double speed_;
  double weight_;
};
```




```
// Car class.

class Car : public Vehicle {
 public:
  Car() : Vehicle() {}

  int GetCapacity();

 private:
  int capacity_;
};
```

```
// Main routine.

int main() {
  Car car;
  cout << car.GetCapacity() << endl;
  cout << car.GetSpeed() << endl;
  cout << car.GetWeight() << endl;
  return 0;
}
```

Another inheritance example



Quiz #1

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

class A {
 protected:
  int member_a;

 public:
  A() { member_a = 1; }
  int GetMember() { return member_a; }
};

class B : public A {
 private:
  int member_b;

 public:
  B() {
    member_a = 10;
    member_b = 20;
  }
  int getSumMembers() {
    return member_a + member_b;
  }
};
```

```
int main() {
  B b;
  cout << b.GetMember() << endl;
  cout << b.GetSumMembers() << endl;

  return 0;
}
```

- What is the expected output of this program? (If a compile error is expected, just write down "error").

Overriding vs. Overloading

- Function overloading (함수 중복정의)
  - provides multiple definitions of function by changing signatures (i.e. changing the number, order, or data type of parameters but leaving the function name the same)
  - can be used without inheritance, in the same scope

```
int Print(int a) { … }

int Print(int a, int b) { … }
```

- **Function overriding (함수 재정의)**
  - **Redefinition of base class function** in the derived class with same signatures

Overriding Member Function

- You can override a member function to provide a custom functionality of the derived class.

- Redefine a member function with the same name as the inherited function.
  - All ancestor's member functions with the same name will be occluded.
  - To access the ancestor's member functions, use `Ancestor::MemberFunction()`.

An example of overriding

```
// Vehicle class.

class Vehicle {
 public:
  Vehicle() {}
  void Accelerate();
  void Decelerate();

  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

 private:
  LatLng location_;
  double speed_;
  double weight_;
};
```

```
// Car class.
class Car : public Vehicle {
 public:
  Car() : Vehicle() {}

  int GetCapacity();

  // Override the parent's GetWeight().
  double GetWeight() {
    return Vehicle::GetWeight() +
        passenger_weight_;
  }
 private:
  int capacity_;
  double passenger_weight_;
};
```

```
// Main routine.
int main() {
  Car car;
  cout << car.GetCapacity() << endl;
  cout << car.GetSpeed() << endl;
  cout << car.GetWeight() << endl;
  return 0;
}
```

An example of overriding

```
// Vehicle class.

class Vehicle {
 public:
  Vehicle() {}
  void Accelerate();
  void Decelerate();

  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

 private:
  LatLng location_;
  double speed_;
  double weight_;
};
```

```
// Car class.
class Car : public Vehicle {
 public:
  Car() : Vehicle() {}

  int GetCapacity();

  // Override the parent's GetWeight().
  double GetWeight() {
    return Vehicle::GetWeight() +
        passenger_weight_;
  }
 private:
  int capacity_;
  double passenger_weight_;
};
```

```
// Main routine.
int main() {
  Car car;
  cout << car.GetCapacity() << endl;
  cout << car.GetSpeed() << endl;
  cout << car.GetWeight() << endl;
  return 0;
}
```

= weight_?

An example of overriding

```
// Vehicle class.

class Vehicle {
 public:
  Vehicle() {}
  void Accelerate();
  void Decelerate();

  LatLng GetLocation();
  double GetSpeed();
  double GetWeight();

 protected:
  LatLng location_;
  double speed_;
  double weight_;
};
```

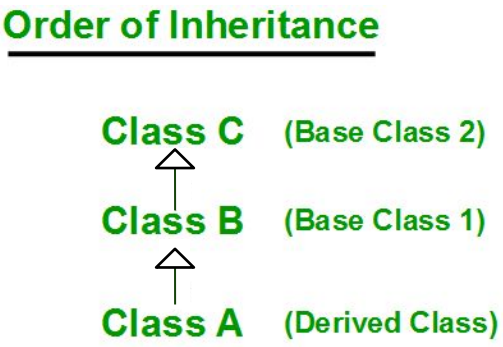
public: everyone can access.
private: only its member functions can access.
protected: its member functions and the member functions of descendant classes can access.

```
// Car class.
class Car : public Vehicle {
 public:
  Car() : Vehicle() {}

  int GetCapacity();

  // Override the parent's GetWeight().
  double GetWeight() {
    return weight_ +
passenger_weight_;
  }
 private:
  int capacity_;
  double passenger_weight_;
};
```

```
// Main routine.
int main() {
  Car car;
  cout << car.GetCapacity() << endl;
  cout << car.GetSpeed() << endl;
  cout << car.GetWeight() << endl;
  return 0;
}
```

Constructor, Destructor & Inheritance

- Constructor and destructor call order:
  - Constructors are called from base class to derived class.
  - Destructor are call in reverse order.



Order of Constructor Call

1. C() (Class C's Constructor)
2. B() (Class B's Constructor)
3. A() (Class A's Constructor)

Order of Destructor Call

1. ~A() (Class A's Destructor)
2. ~B() (Class B's Destructor)
3. ~C() (Class C's Destructor)

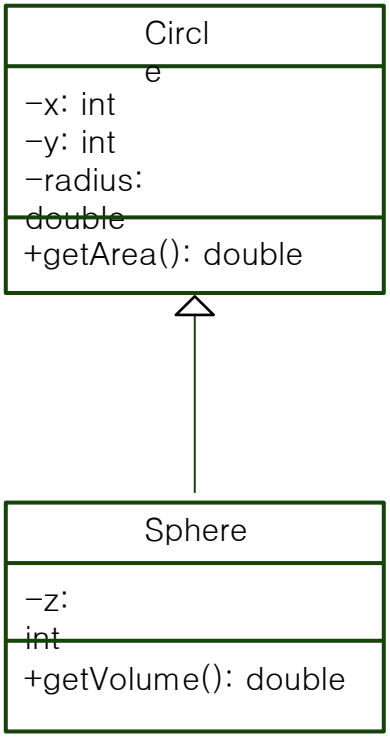
Constructor, Destructor & Inheritance: Example 1

```
class Parent {
 public:
  Parent() { cout << " Parent"; }
  ~Parent() { cout << " ~Parent"; }
};

class Child : public Parent {
 public:
  Child() { cout << " Child"; }
  ~Child() { cout << " ~Child"; }
};

class Test : public Child {
 public:
  Test() { cout << " Test"; }
  ~Test() { cout << " ~Test"; }
};
```

```
int main() {
  {
    Child child;
    cout << endl;
  }
  cout << endl;
  {
    Test test;
    cout << endl;
  }
  cout << endl;
  return 0;
}
```

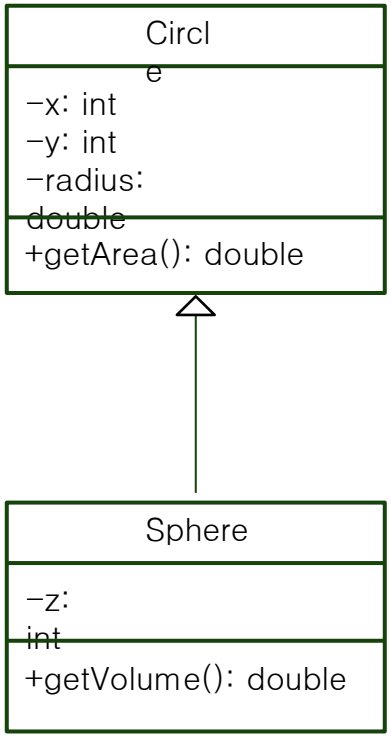
```
Parent Child
~Child ~Parent
Parent Child Test
~Test ~Child ~Parent
```

Constructor, Destructor & Inheritance: Example 2




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

class Circle {
private:
    int x, y;
    double radius;
public:
    Circle(int px, int py, double pradius) {
        x=px; y=py; radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

class Sphere: public Circle{
private:
    int z;
public:
    Sphere(int px, int py, double pradius, int pz){
        cout << "Sphere" << endl;
        x=px; y=py; radius=pradius; z=pz;}
    double getVolumn(){
        return 4.0/3*3.14*radius*radius*radius;
    }
};

int main()
{
    Circle c(2,3,4.0);
    cout << c.getArea() << endl;
    Sphere s(2,3,4.0,5);
    cout << s.getVolumn() << endl;
    return 0;
}
```

Constructor, Destructor & Inheritance: Example 2

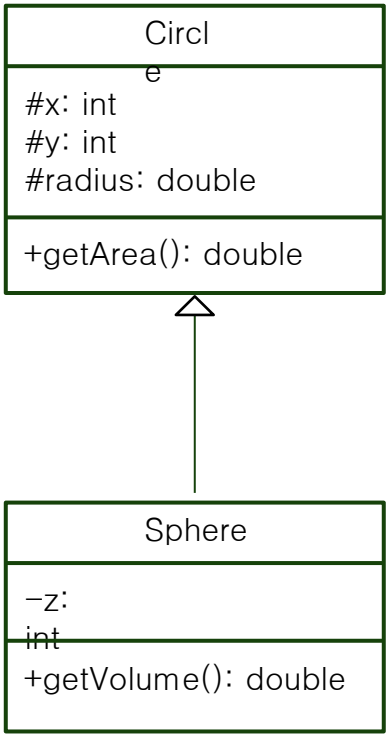



```
#include <iostream>
using namespace std;

class Circle {
private:
    int x, y;
    double radius;
public:
    Circle(int px, int py, double pradius) {
        x=px; y=py; radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

class Sphere: public Circle{
private:
    int z;
public:
    Sphere(int px, int py, double pradius, int pz){
        cout << "Sphere" << endl;
        x=px; y=py; radius=pradius; z=pz;}
    double getVolumn(){
        return 4.0/3*3.14*radius*radius*radius;
```

implicitly calls Circle's default constructor which is not defined

```
8_10.cc:18:5: error: constructor for 'Sphere' must explicitly initialize the
      base class 'Circle' which does not have a default constructor
    Sphere(int px, int py, double pradius, int pz){
    ^
8_10.cc:4:7: note: 'Circle' declared here
class Circle {
      ^
8_10.cc:20:9: error: 'x' is a private member of 'Circle'
        x=px; y=py; radius=pradius; z=pz;}
        ^
8_10.cc:6:9: note: declared private here
    int x, y;
```

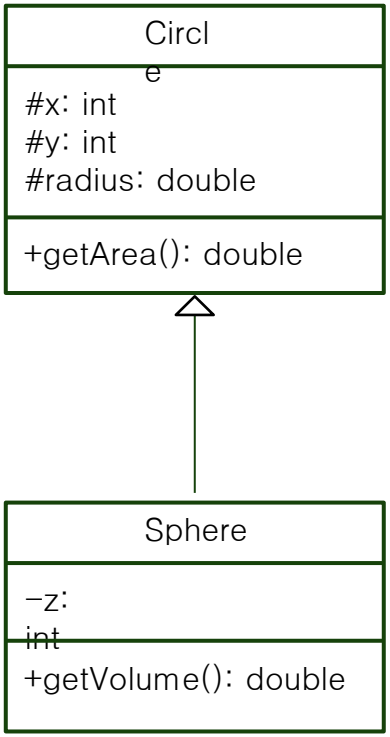
Constructor, Destructor & Inheritance: Example 2




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

class Circle {
protected:
    int x, y;
    double radius;
public:
    Circle(){ cout << "Circle: no parameter" << endl;  }
    Circle(int px, int py, double pradius) {
        cout << "Circle: with parameters" << endl;
        x=px; y=py; radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

class Sphere: public Circle{
private:
    int z;
public:
    Sphere(int px, int py, double pradius, int pz){
        cout << "Sphere" << endl;
        x=px; y=py; radius=pradius; z=pz;}
    double getVolumn(){
        return 4.0/3*3.14*radius*radius*radius;
    }
};

int main()
{
    Circle c(2,3,4.0);
    cout << c.getArea() << endl;
    Sphere s(2,3,4.0,5);
    cout << s.getVolumn() << endl;
    return 0;
}
```

```
Circle: with parameters
50.24
Circle: no parameter
Sphere
267.947
```

Constructor, Destru

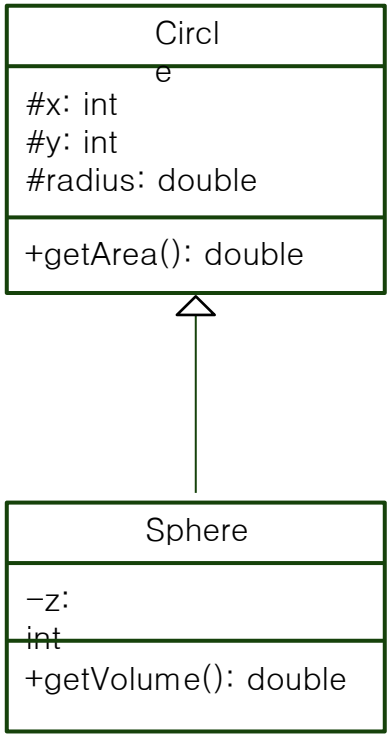



```
#include <iostream>
using namespace std;

class Circle {
protected:
    int x, y;
    double radius;
public:

    Circle(int px, int py, double pradius) {
        cout << "Circle: with parameters" << endl;
        x=px; y=py; radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

class Sphere: public Circle{
private:
    int z;
public:
    //Sphere(int px, int py, double pradius, int pz){
    //  cout << "Sphere" << endl;
    //      x=px; y=py; radius=pradius; z=pz;}
    Sphere(int px, int py, double pradius, int pz):
      Circle(px, py, pradius), z(pz){
        cout << "Sphere" << endl;
      }
    double getVolumn(){
        return 4.0/3*3.14*radius*radius*radius;
    }
};

int main()
{
    Circle c(2,3,4.0);
    cout << c.getArea() << endl;
    Sphere s(2,3,4.0,5);
    cout << s.getVolumn() << endl;
    return 0;
}
```

explicitly calls Circle's constructor

```
Circle: with parameters
50.24
Circle: with parameters
Sphere
267.947
```

Constructor, Dest




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

class Circle {
protected:
    int x, y;
    double radius;
public:
    //Circle(){ cout << "Circle: no parameter" << endl;  }
    //Circle(int px, int py, double pradius) {
    //    cout << "Circle: with parameters" << endl;
    //    x=px; y=py; radius=pradius;}
    double getArea() { return 3.14*radius*radius; }
};

class Sphere: public Circle{
private:
    int z;
public:
    Sphere(int px, int py, double pradius, int pz){
        cout << "Sphere" << endl;
          x=px; y=py; radius=pradius; z=pz;}
    //Sphere(int px, int py, double pradius, int pz):
    //  Circle(px, py, pradius), z(pz){
    //    cout << "Sphere" << endl;
    //  }
    double getVolumn(){
        return 4.0/3*3.14*radius*radius*radius;
    }
};

int main()
{
  //Circle c(2,3,4.0);
  //  cout << c.getArea() << endl;
    Sphere s(2,3,4.0,5);
    cout << s.getVolumn() << endl;
    return 0;
}
```

```
Sphere
267.947
```

Quiz #2

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

class A {
 protected:
  int member_a;

 public:
  A(int n) : member_a(n) { }
  int GetMember() { return member_a; }
};

class B : public A {
 private:
  int member_b;

 public:
  B() {
    member_a = 10;
    member_b = 20;
  }
  int GetMember() { return member_b; }
};
```

```
int main() {
  A a(1);
  cout << a.GetMember() << endl;

  B b;
  cout << b.GetMember() << endl;

  return 0;
}
```

- What is the expected output of this program? (If a compile error is expected, just write down "error").

Person Example - outline

```
// Person class.

class Person {
 public:
  Person(const string& name);

  const string& name();
  const string& address();
  void ChangeAddress(const string&
addr);
};

// Student class.

class Student : public Person {
 public:
  Student(const string& name);

  void RegisterClass(int class_id);
  int GetNumClasses();
  int ComputeTuition();
};
```

```
// Employee class

class Employee : public Person {
 public:
  Employee(
      const string& name, int salary);

  int salary();
  int ComputeIncomeTax();
  void SetSalary(int salary);
};

// Faculty class

class Faculty : public Employee {
 public:
  Faculty(
      const string& name, int salary);

  void TeachClass(int class_id);
};
```

Person Example - implementation

person.h

```
#ifndef _PERSON_H_
#define _PERSON_H_

#include <string>

class Person {
 public:
  Person(const std::string& name)
      : name_(name) {}

  const std::string& name() {
    return name_;
  }
  const std::string& address() {
    return address_;
  }

  void ChangeAddress(const std::string& addr) {
    address_ = addr;
  }

 private:
  std::string name_, address_;
};

#endif
```

student.h

```
#ifndef _STUDENT_H_
#define _STUDENT_H_

#include <set>
#include "person.h"

class Student : public Person {
 public:
  Student(const std::string& name)
      : Person(name) {}

  void RegisterClass(int class_id) {
    registered_classes_.insert(class_id);
  }

  int GetNumClasses() {
    return registered_classes_.size();
  }

  int ComputeTuition() {
    return registered_classes_.size() * 100
        + 500;
  }

 private:
  std::set<int> registered_classes_;
};

#endif
```

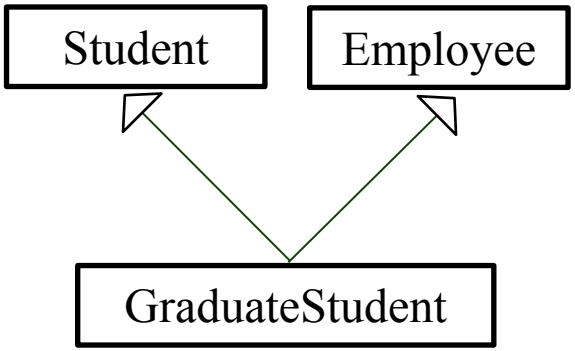
Person Example - implementation

main.cc

```
#include "employee.h"
#include "faculty.h"
#include "student.h"
using namespace std;

int main() {
  Student john("John"), david("David");
  Employee susan("Susan", 200);
  Faculty daniel("Daniel", 100);

  john.ChangeAddress("New York");
  david.RegisterClass(101);
  daniel.TeachClass(101);
  daniel.TeachClass(102);

  return 0;
}
```

Multiple Inheritance

- Inheriting from two or more base classes.
  - The derived class has all the members of base classes



- Issues
  - Ambiguity
    - What happens if base classes has same-named members?
  - The diamond problem
    - What happens if parent classes are derived from the same grandparent class?

Multiple Inheritance: Example

```
class Person {
 public:
  // ...
};

class Student : public Person {
 public:
  // ...
};

class Employee : public Person {
 public:
  // ...
};

// Multiple inheritance example.
class GraduateStudent
    : public Student, public Employee {
 public:
  GraduateStudent(const string& name,
                  int salary)
      : Student(name),
        Employee(name + "*", salary) {}
};
```

```
int main() {
  GraduateStudent mark("Mark", 50);

  cout << mark.GetNumClasses()
       << endl;
  cout << mark.salary() << endl;
  return 0;
}
```

Multiple Inheritance: Example

```
class Person {
 public:
  // ...
};

class Student : public Person {
 public:
  // ...
  void DoSomething();
};

class Employee : public Person {
 public:
  // ...
  void DoSomething();
};

// Multiple inheritance example.
class GraduateStudent
    : public Student, public Employee {
 public:
  GraduateStudent(const string& name,
                  int salary)
      : Student(name),
        Employee(name + "*", salary) {}
};
```

```
int main() {
  GraduateStudent mark("Mark", 50);

  // Error - ambiguous function
  //   DoSomething()
  mark.DoSomething();

  return 0;
}
```

Multiple Inheritance

- Actually, you can avoid these problem by using `virtual` inheritance in C++.

- General advice: Avoid using multiple inheritance as much as possible.
  - It is commonly believed that multiple inheritance tends to mass things up.
  - That's why Java forbids multiple inheritance.

- Note that multiple inheritance from *interfaces* (pure abstract classes in C++) can be very helpful.
  - Java only allows multiple inheritance from *interfaces* ("implements" multiple interfaces in Java)

const: review

- Const variables

  const int MAX = 100;

- Const parameters

  int sum(const int x, const int y) { . . . }

- Pointer to const and const pointer

  const int *pNum = &num

  int* const p = &a;

const & Class

- Const member variables
  - should be initialized in *member initializer list* of constructor
- **Const member functions**
  - Can read the value of member variables
  - Cannot change the value of member variables
- Const object
  - Cannot change the value of member variables on a const object
  - **Cannot call non-const member functions on a const object**

const: member variables

```
class Circle {
 private:
  double radius;
  const double PI;

 public:
  Circle(double r, double p) {
    radius = r, PI = p;   // ???
  }

  void SetRadius(double r) {
    radius = r;
  }

  double GetArea() const {
    return PI * radius * radius;
  }
};
```

```
int main() {
  Circle cir(2.0, 3.1415);
  cout << cir.GetArea() << endl;
  return 0;
}
```

const: member variables

```
class Circle {
 private:
  double radius;
  const double PI;

 public:
  Circle(double r, double p)
      : radius(r), PI(p) {}

  void SetRadius(double r) {
    radius = r;
  }

  double GetArea() const {
    return PI * radius * radius;
  }
};
```

```
int main() {
  Circle cir(2.0, 3.1415);
  cout << cir.GetArea() << endl;
  return 0;
}
```

- Const member variables
  - should be initialized in *member initializer list* of constructor

const: member function

```
class Circle {
 private:
  double radius;
  const double PI;

 public:
  Circle(double r, double p)
      : radius(r), PI(p) {}

  void SetRadius(double r) {
    radius = r;
  }

  double GetArea() const {
    return PI * radius * radius;
  }
};
```

```
int main() {
  Circle cir(2.0, 3.1415);

  cir.SetRadius(4.0);
  cout << cir.GetArea() << endl;
  return 0;
}
```

- Const member functions
  - Can read member variables, cannot update member variables

const: object

```
class Circle {
 private:
  double radius;
  const double PI;

 public:
  Circle(double r)
      : radius(r), PI(3.141592) {}

  void SetRadius(double r) {
    radius = r;
  }

  double GetArea() const {
    return PI * radius * radius;
  }
};
```

```
int main() {
  Circle cir(2.0);
  cout << cir.GetArea() << endl;

  cir.SetRadius(3.0);
  cout << cir.GetArea() << endl;

  const Circle cir2(3.0);
  cout << cir.GetArea() << endl;
  cir.SetRadius(4.0);  // Error
  cout << cir2.GetArea() << endl;

  return 0;
}
```

- Const object
  - Cannot update member variables
  - **Cannot call non-const member functions**

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

class A {
 protected:
  int member_a;

 public:
  A(int n) : member_a(n) {}                  // 1)
  int GetA() const { return member_a; }      // 2)
};

class B: public A {
 private:
  const int member_b;                        // 3)

 public:
  B(int n) : A(n / 2), member_b(n) {}        // 4)
  int GetB() { return member_b; }            // 5)
};

int main() {
  const B b(20);                             // 6)
  cout << b.GetA() << endl;                  // 7)
  cout << b.GetB() << endl;                  // 8)

  return 0;
}
```

Quiz #3

- Which line number from 1) to 8) generates a compile error?
  - Submit 0) if no error is expected

Class Inheritance Types

- Types of inheritance: `public`, `protected`, and `private`.
  - Depending on the inheritance types, the parent's member has different access control ***in the child class***.
  - Most commonly used is **public inheritance** (and probably it's the only useful inheritance).

Type of inheritance	Parent's public member	Parent's protected member	Parent's private member
public	public	protected	x (not accessible)
protected	protected	protected	x (not accessible)
private	private	private	x (not accessible)

Example of Private Inheritance

```
class A {
 public:
  void APublic() {}
 protected:
  void AProtected() {}
 private:
  void APrivate() {}
};

// Private inheritance.
class CA : private A {
 public:
  void CAPublic() {
    APublic();      // OK.
    AProtected();   // OK.
    APrivate();     // Error.
  }
  void CAPublic2() {}
 protected:
  void CAProtected() {
  }
 private:
  void CAPrivate() {
  }
};
```

```
class Client : public CA {
  void Function() {
    APublic();       // Error.
    AProtected();    // Error.
    APrivate();      // Error.

    CAPublic();      // Error.
    CAPublic2();     // OK.
    CAProtected();   // OK.
    CAPrivate();     // Error.
  }
};
```

```
// Main routine.

int main() {
  CA ca;
  ca.APublic();    // Error.
  ca.CAPublic();   // Error
  ca.CAPublic2();  // OK.
  ...
}
```

Next Time

- Next lecture:
  - 9 - Polymorphism 1