



Module 28

Partha Pratim
Das

Objectives &
Outline

Virtual
Destructor

Pure Virtual
Function

Abstract Base
Class

Summary

Module 28: Programming in C++

Dynamic Binding (Polymorphism): Part 3

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Module Objectives

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Virtual
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Summary

- Understand why destructor must be virtual in a class hierarchy
- Learn to work with class hierarchy



Module Outline

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Summary

- Virtual Destructor
- Pure Virtual Function
- Abstract Base Class



Virtual Destructor

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Summary

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

class B {
    int data_;
public:
    B(int d) :data_(d) { cout << "B()" << endl; }
    ~B() { cout << "~B()" << endl; }
    virtual void Print() { cout << data_; }
};

class D: public B {
    int *ptr_;
public:
    D(int d1, int d2) :B(d1), ptr_(new int(d2)) { cout << "D()" << endl; }
    ~D() { cout << "~D()" << endl; delete ptr_; }
    void Print() { B::Print(); cout << " " << *ptr_; }
};

int main() {
    B *p = new B(2);
    B *q = new D(3, 5);

    p->Print(); cout << endl;
    q->Print(); cout << endl;

    delete p;
    delete q;

    return 0;
}
```

Output:

```
B()
B()
D()
2
3 5
~B()
~B()
```

Destructor of d (type D) not called!



Virtual Destructor

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Summary

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

class B {
    int data_;
public:
    B(int d) :data_(d) { cout << "B()" << endl; }
    virtual ~B() { cout << "~B()" << endl; } // Destructor made virtual
    virtual void Print() { cout << data_; }
};

class D: public B {
    int *ptr_;
public:
    D(int d1, int d2) :B(d1), ptr_(new int(d2)) { cout << "D()" << endl; }
    ~D() { cout << "~D()" << endl; delete ptr_; }
    void Print() { B::Print(); cout << " " << *ptr_; }
};

int main() {
    B *p = new B(2);
    B *q = new D(3, 5);

    p->Print(); cout << endl;
    q->Print(); cout << endl;

    delete p;
    delete q;

    return 0;
}
```

Output:

```
B()
B()
D()
2
3 5
~B()
~D()
~B()
```

Destructor of d (type D) is called!



Virtual Destructor

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Summary

- If the destructor is not virtual in a polymorphic hierarchy, it leads to **Slicing**
- **Destructor must be declared virtual in the base class**



Hierarchy of Shapes

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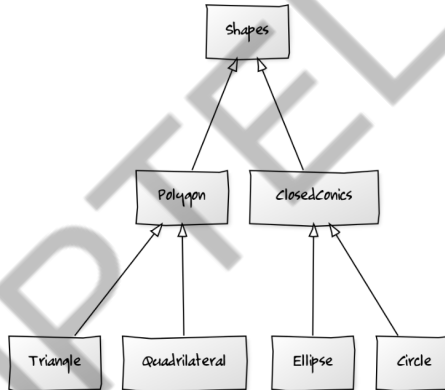
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Summary



- We want to have a polymorphic `draw()` function for the hierarchy
- `draw()` will be overridden in every class based on the drawing algorithms
- What is the `draw()` function for the root `Shapes` class?



Pure Virtual Function

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Summary

- For the polymorphic hierarchy of Shapes, we need `draw()` to be a virtual function
- `draw()` must be a member of Shapes class for polymorphic dispatch to work
- But we cannot define the body of `draw()` function for the root Shapes class as we do not have an algorithm to draw an arbitrary shape. In fact, we cannot even have a representation for shapes in general!
- **Pure Virtual Function** solves the problem
- A **Pure Virtual Function** has a signature but no body!



Abstract Base Class

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Summary

- A class containing at least one **Pure Virtual Function** is called an **Abstract Base Class**
- **Pure Virtual Functions** may be inherited or defined in the class
- No instance can be created for an **Abstract Base Class**
- Naturally it does not have a constructor or the destructor
- An **Abstract Base Class**, however, may have other virtual (non-pure) and non-virtual member functions as well as data members
- Data members in an **Abstract Base Class** should be protected. Of course, private and public data are also allowed
- Member functions in an **Abstract Base Class** should be public. Of course, private and protected methods are also allowed
- A **Concrete Class** must override and implement all **Pure Virtual Functions** so that it can be instantiated



Shape Hierarchy

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Summary

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

class Shapes { public:                                // Abstract Base Class
    virtual void draw() = 0; // Pure Virtual Function
};
class Polygon : public Shapes {                       // Concrete Class
    void draw() { cout << "Polygon: Draw by Triangulation" << endl; }
};
class ClosedConics : public Shapes {                 // Abstract Base Class
    // draw() inherited - Pure Virtual
};
class Triangle : public Polygon { public:            // Concrete Class
    void draw() { cout << "Triangle: Draw by Lines" << endl; }
};
class Quadrilateral : public Polygon { public:       // Concrete Class
    void draw() { cout << "Quadrilateral: Draw by Lines" << endl; }
};
class Circle : public ClosedConics { public:         // Concrete Class
    void draw() { cout << "Circle: Draw by Bresenham Algorithm" << endl; }
};
class Ellipse : public ClosedConics { public:        // Concrete Class
    void draw() { cout << "Ellipse: Draw by ..." << endl; }
};
int main() {
    Shapes *arr[] = { new Triangle, new Quadrilateral, new Circle, new Ellipse };

    for (int i = 0; i < sizeof(arr) / sizeof(Shapes *); ++i) arr[i]->draw();
    // ...
    return 0;
}
```

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Shape Hierarchy

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```
int main() {  
    Shapes *arr[] = { new Triangle, new Quadrilateral, new Circle, new Ellipse };  
  
    for (int i = 0; i < sizeof(arr) / sizeof(Shapes *); ++i) arr[i]->draw();  
    // ...  
    return 0;  
}
```

Output:

Triangle: Draw by Lines

Quadrilateral: Draw by Lines

Circle: Draw by Bresenham Algorithm

Ellipse: Draw by ...

- Instances for class Shapes and class ClosedConics cannot be created



Shape Hierarchy:

A Pure Virtual Function may have a body!

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```
#include <iostream>
using namespace std;
class Shapes { public:                                // Abstract Base Class
    virtual void draw() = 0 // Pure Virtual Function
    { cout << "Shapes: Init Brush" << endl; }
};
class Polygon: public Shapes {                        // Concrete Class
    void draw() { Shapes::draw(); cout << "Polygon: Draw by Triangulation" << endl; }
};
class ClosedConics : public Shapes {                  // Abstract Base Class
    // draw() inherited - Pure Virtual
};
class Triangle : public Polygon { public:             // Concrete Class
    void draw() { Shapes::draw(); cout << "Triangle: Draw by Lines" << endl; }
};
class Quadrilateral : public Polygon { public:        // Concrete Class
    void draw() { Shapes::draw(); cout << "Quadrilateral: Draw by Lines" << endl; }
};
class Circle : public ClosedConics { public:          // Concrete Class
    void draw() { Shapes::draw(); cout << "Circle: Draw by Bresenham Algorithm" << endl; }
};
class Ellipse : public ClosedConics { public:         // Concrete Class
    void draw() { Shapes::draw(); cout << "Ellipse: Draw by ..." << endl; }
};
int main() {
    Shapes *arr[] = { new Triangle, new Quadrilateral, new Circle, new Ellipse };

    for (int i = 0; i < sizeof(arr) / sizeof(Shapes *); ++i) arr[i]->draw();
    // ...
    return 0;
}
```



Shape Hierarchy

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```
int main() {  
    Shapes *arr[] = { new Triangle, new Quadrilateral, new Circle, new Ellipse };  
  
    for (int i = 0; i < sizeof(arr) / sizeof(Shapes *); ++i) arr[i]->draw();  
    // ...  
    return 0;  
}
```

Output:

```
Shapes: Init Brush  
Triangle: Draw by Lines  
Shapes: Init Brush  
Quadrilateral: Draw by Lines  
Shapes: Init Brush  
Circle: Draw by Bresenham Algorithm  
Shapes: Init Brush  
Ellipse: Draw by ...
```

- Instances for class Shapes and class ClosedConics cannot be created



Module Summary

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Summary

- Discussed why destructors must be virtual
- Introduced Pure Virtual Functions
- Introduced Abstract Base Class



Instructor and TAs

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Summary

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