Programming Paradigms

Data Abstraction and Object-Orientation (Part 3)

Prof. Dr. Michael Pradel

Software Lab, University of Stuttgart

Summer 2020

Overview

- Encapsulation and Information Hiding
- Inheritance
- Initialization and Finalization 
- Dynamic Method Binding
- Mix-in and Multiple Inheritance

Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```

Please vote via Ilias.

Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```

Result: `ABC~C~B~A`

Please vote via Ilias.

Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```

Implicitly creates object of class `C`

Result: `ABC~C~B~A`

Please vote via Ilias.

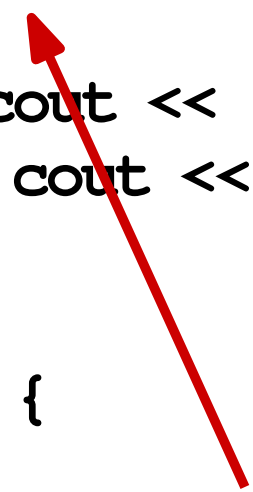
Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```



Class with two superclasses

Result: `ABC~C~B~A`

Please vote via Ilias.

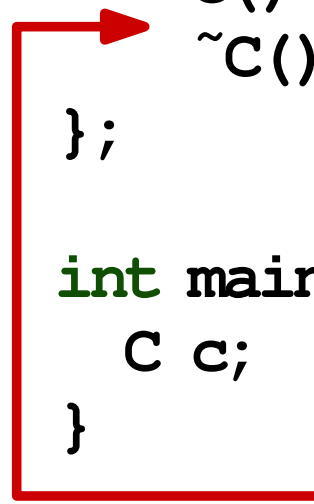
Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```



Constructor and destructor

Result: `ABC~C~B~A`

Please vote via Ilias.

Quiz

What does the following C++ code print?

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```

Result: `ABC~C~B~A`

Execution order of constructors and destructors

Please vote via Ilias.

Initialization

- **Each class: Zero, one, or more constructors**
- **Distinguished by**
  - Number and type of arguments (C++, Java, C#)
  - Name of the constructor (Eiffel)

Example: Eiffel Constructors

```
class COMPLEX
creation
  new_cartesian, new_polar
feature {ANY}
  x, y: REAL

  new_cartesian(x_val, y_val : REAL) is
    -- (...) constructor implementation

  new_polar(rho, theta : REAL) is
    -- (...) constructor implementation

  -- (...) other members
end
```

Implicit vs. Explicit Initialization

- **Some PLs (e.g., Java): Constructor must always be called explicitly**
- **Other PLs (e.g., C++): Constructor sometimes called implicitly**
  - Value model of variables: Object must be initialized
  - Declarating a variable implicitly calls zero-argument constructor

Implicit vs. Explicit Initialization (2)

Example: Java

```
class Foo { ... }

Foo f;
```

- Uninitialized reference to a `Foo` object
- Has value `null`

Example: C++

```
class Foo { ... }

Foo f;
```

- Implicitly initialized with `Foo`'s default constructor
- Variable contains the object

Superclass Constructors

- During initialization of subclass, also initialize inherited superclass fields

```
// Java example
class A { ... }

class B extends A {
  B(int k) {
    super(k);
  }
}
```

```
// C++ example
class A { ... }

class B : public A {
  public:
  B(int k) : A(k) {
     ..
  }
}
```

Superclass Constructors

- During initialization of subclass, also initialize inherited superclass fields

```
// Java example
class A { ... }

class B extends A {
  B(int k) {
    super(k);
  }
}
```

```
// C++ example
class A { ... }

class B : public A {
  public:
  B(int k) : A(k) {
     ..
  }
}
```

Call to super constructor

Execution Order of Constructors

- **Constructor(s) of base class(es) execute before constructors of subclass**
  - C++: Implicit in PL
  - Java: Enforced by not allowing any statement before `super()`

Destructors

- **In some PLs (e.g., C++), each class can define a destructor**
- **Called when**
  - Object goes out of scope
  - `delete` operator called on object
- **Optional, but highly recommended if class dynamically allocates memory**
  - Must free memory in destructor (otherwise: memory leak)

Destructors: Example

```
// C++ example
cout << string("Hi there").length(); // prints 8
```

Destructors: Example

```
// C++ example
cout << string("Hi there").length(); // prints 8
```

- First, calls `string(const char*)` constructor
- Afterwards, calls `~string()` destructor because object goes out of scope

Execution Order of Destructors

- **Destructor of subclass called before destructor(s) of superclass(es)**
  - Reverse order of constructors
  - Intuition: First clean up added state, then inherited state

Example (Again)

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

```
class C :
    public A, private B {
  public:
    C() { cout << "C"; }
    ~C() { cout << "~C"; }
};

int main() {
  C c;
}
```

Result: ABC~C~B~A

Finalization

- **Java and C#: No destructors but finalizers**
- **Called immediately before object gets garbage-collected**
  - Use to clean up resources, e.g., file handles
  - Note: May never be called, e.g., in short-running programs
    - `finalize` has been deprecated in Java 9

Demo

Immortal.java