Computer Programming

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Session: Polymorphism and Virtual Functions

Recap

- Objects of base and derived classes
- Objects of classes with pointers and references
- Inheritance
  - Multiple
  - Diamond

Overview of This Lecture

- Recapitulating ‘printInfo’ of base and derived classes
- Polymorphism
- Virtual destructor
- Abstract class

Polymorphism

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What is Polymorphism?

Dictionary Meaning

The condition of **occurring** in several **different forms**

or

The ability to **assume different forms** or **shapes**.

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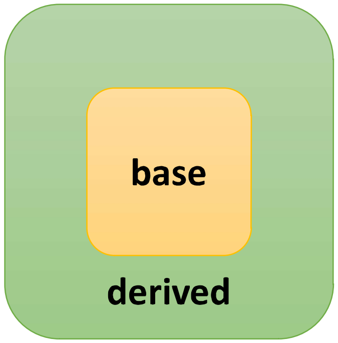
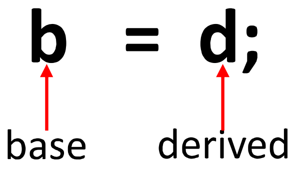
Greek: **polys** → **many, much**

morphē → **form, shape**

Already seen in some forms





b = d;

Object ‘d’ being an object of derived class, can also be viewed as an object of base class (has all members of the base class)

Thus, object ‘d’ can be viewed as having multiple ‘forms’

Examining printInfo() from savings and current

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```
class base {
  public:
    int id; float balance;
    void printInfo() {
      cout << "base\n";
    }
};
```

```
class savings : public base {
  public:
    int age; long int ATM;
    void printInfo() {
      cout << "savings\n";
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;
    void printInfo() {
      cout << "current\n";
    }
};
```

```
int main() {
  base b; savings s; current c;

  base *bptr;
  bptr = &s;
  bptr->printInfo();

  bptr = &c;
  bptr->printInfo();
  return 0;
}
```

address of ‘s’ assigned to base pointer

address of ‘c’ assigned to base pointer

Output

```
base
base
```

How to print info from ‘savings’ and ‘current’ by invoking bptr->printInfo()?

How do we solve ?

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We want ‘bptr->printInfo();’ to behave as
(1) printInfo() in ‘savings’ after ‘bptr = &s;’
(2) printInfo() in ‘current’ after ‘bptr = &c;’

Solution: Virtual functions

Polymorphism

Polymorphism

```
class base {
  public:
    int id; float balance;

    virtual void printInfo() {
      cout << "base\n";
    }
};
```

```
class savings : public base {
  public:
    int age; long int ATM;

    void printInfo() {
      cout << "savings \n";
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;

    void printInfo() {
      cout << "current \n";
    }
};
```

```
int main() {
  base b; savings s;
  current c;

  base * bptr = &s;

  bptr->printInfo();

  bptr = &c;

  bptr->printInfo();

  return 0;
}
```

Assigning addr of 'savings' object to 'base' pointer

print info from the 'savings' object

Assigning addr of ‘current' object to 'base' pointer

print info from the ‘current' object

Output

savings

current

Polymorphism

```
class base {
  public:
    int id; float balance;
    void call() { cout << "base call\n";  }
    virtual void printInfo() {
      cout << "base\n";
    }
};
```

```
class savings : public base {
  public:
    int age; long int ATM;
    void call() { cout << "savings call\n"; }
    void printInfo() {
      cout << "savings \n";
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;
    void call() { cout << "current call\n"; }
    void printInfo() {
      cout << "current \n";
    }
};
```

```
int main() {
  base b; savings s;
  current c;

  base * bptr = &s;
  bptr->call();
  bptr->printInfo();

  bptr = &c;
  bptr->call();
  bptr->printInfo();

  return 0;
}
```

Output

base call

savings

base call

current

Polymorphism: A different variant

```
class base {
  public:
    int id;
    float balance;
    void print() { printInfo();}
    virtual void printInfo() {
      cout << "base\n";
    }
};
```

```
class savings : public base {
  public:
    int age;  long int ATM;
    void printInfo() {
      cout << "savings\n" ;
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;
    void printInfo() {
      cout << "current\n";
    }
};
```

```
int main() {
  base b;
  savings s;
  current c;

  b.print();

  s.print();

  c.print();

  return 0;
}
```

calls 'printInfo' from the 'base' object

calls 'printInfo' from the ‘savings' object

calls 'printInfo' from the ‘current' object

Output

base

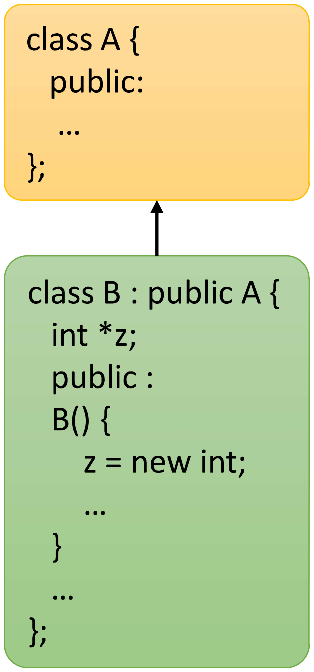
savings

current

Virtual Destructor

Problem Overview:

- 2 classes, ‘class A’ and ‘class B’.
- ‘B’ inherits from ‘A’.
- ‘aptr’ is of type ‘A*’
- Object pointed by ‘aptr’ is of type ‘B’
- Private data member ‘z’ of class ‘B’



```
class A {
  public:
   …
};
```

```
class B : public A {
  int *z;
  public :
  B() {
     z = new int;
     …
  }
  …
};
```

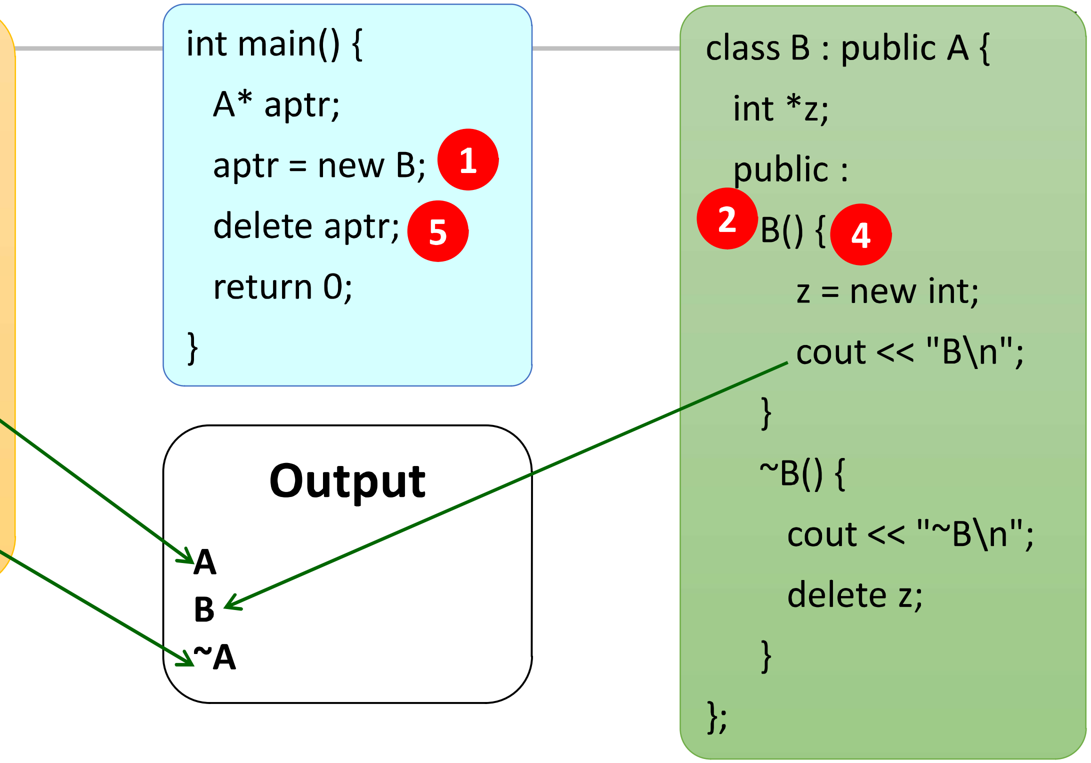
```
int main() {
   A* aptr;
   aptr = new B;
   …
}
```

Problem Definition:

- How to **delete resources/memory** occupied by the **derived class using the ‘base’** class pointer ?

Motivation: Virtual Destructor

```
class A {
  public:
    A() { 3
        cout << "A\n";
    }
    ~A() { 6
        cout << "~A\n";
    }
};
```



```
int main() {
  A* aptr;
  aptr = new B; 1
  delete aptr; 5
  return 0;
}
```

Output

```
A
B
~A
```

```
class B : public A {
  int *z;
  public :
  2 B() { 4
      z = new int;
      cout << "B\n";
    }
    ~B() {
      cout << "~B\n";
      delete z;
    }
};
```

	Memory for int z			
Addresses	1001	1002	1003	1004
	Value of int *z			

Program terminated

Base destructor not called

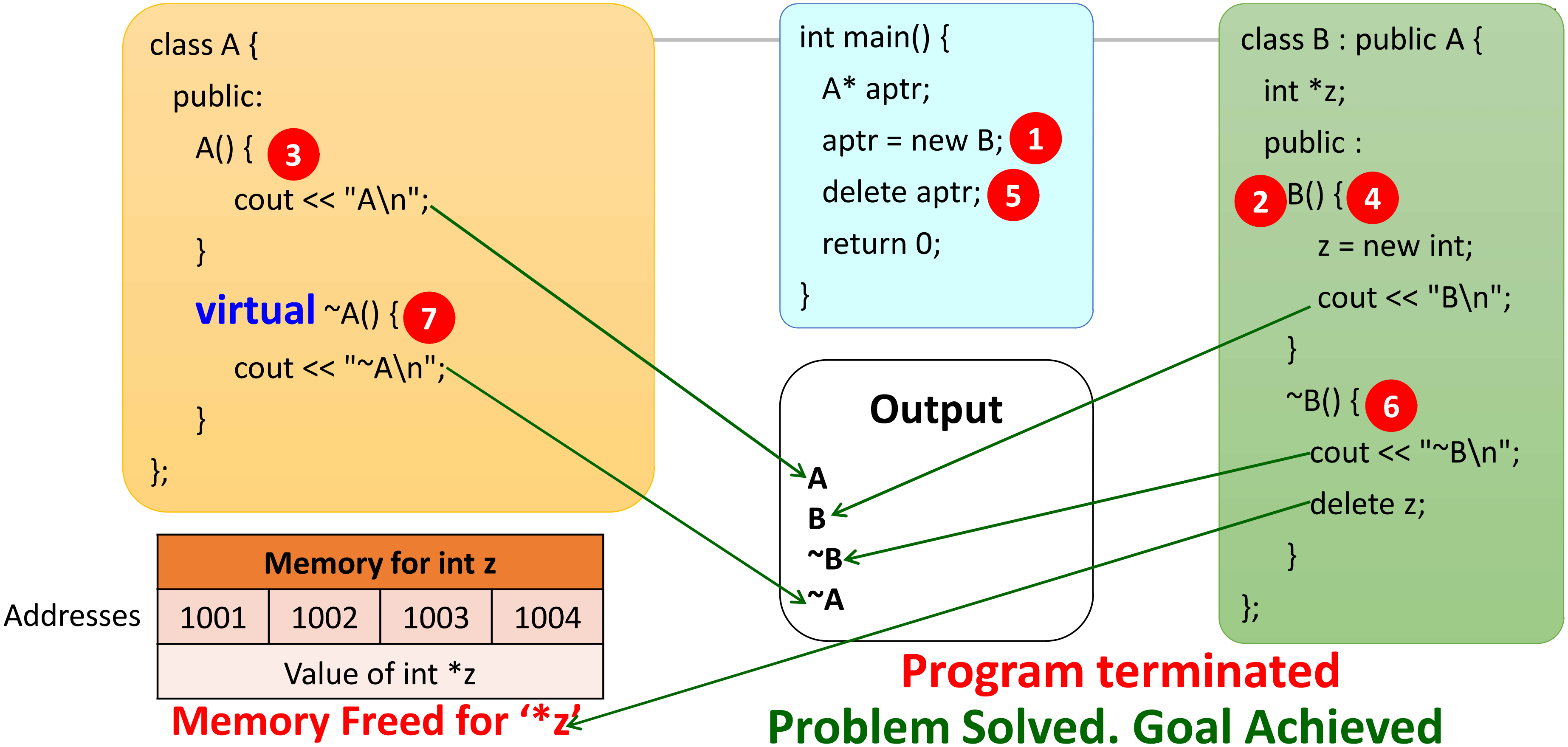
Memory for 'z' not freed. Hence, problem NOT solved

Proposed solution: Virtual destructor

To enforce that destructor ‘B’ is called:

Sol: Declare destructor of ‘A’ as virtual

Virtual Destructor



```
class A {
  public:
    A() {  3
        cout << "A\n";
    }
    virtual ~A() {  7
        cout << "~A\n";
    }
};
```

```
int main() {
    A* aptr;
    aptr = new B;  1
    delete aptr;  5
    return 0;
}
```

```
class B : public A {
    int *z;
    public :
  2 B() {  4
        z = new int;
        cout << "B\n";
    }
    ~B() {  6
       cout << "~B\n";
       delete z;
    }
};
```

Output

```
A
B
~B
~A
```

	Memory for int z			
Addresses	1001	1002	1003	1004
	Value of int *z			

Memory Freed for '*z'

Program terminated

Problem Solved. Goal Achieved

Abstract class

Abstract class is:

- A class that cannot be instantiated directly
- Implemented as a class that has one or more **pure virtual functions**
    - Which should be overridden by member function definitions of derived class

When should we use it

- When using the base class directly has no meaningful purpose
- i.e. It makes sense to use it only as a derived class

Example (Bank account – already examined)

- A person does not have **just a bank account**.
- It is either a **savings bank account** or a **current bank account**
- Instantiating class ‘base’ by itself has no meaningful purpose

Abstract class: Example 1

```
class base {
  public:
    int id; float balance;
    virtual void call() = 0;
    virtual void printInfo() = 0;
};
```

```
class savings : public base {
  public:
    int age; long int ATM;
    void call() {
      cout << "savings call\n";
    }
    void printInfo() {
      cout << "savings \n";
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;
    void call() {
      cout << "current call\n";
    }
    void printInfo() {
      cout << "current \n";
    }
};
```

```
int main() {
❌//base B;
  base *b;
  savings s;

  b = &s;
  b->call();
  b->printInfo();

  current c;
  b = &c;
  b->call();
  b->printInfo();

  return 0;
}
```

Compile Error

Cannot declare variable 'B' to be of abstract class type 'base'

assigning 'savings' object to 'base' pointer

print info from the 'savings' object

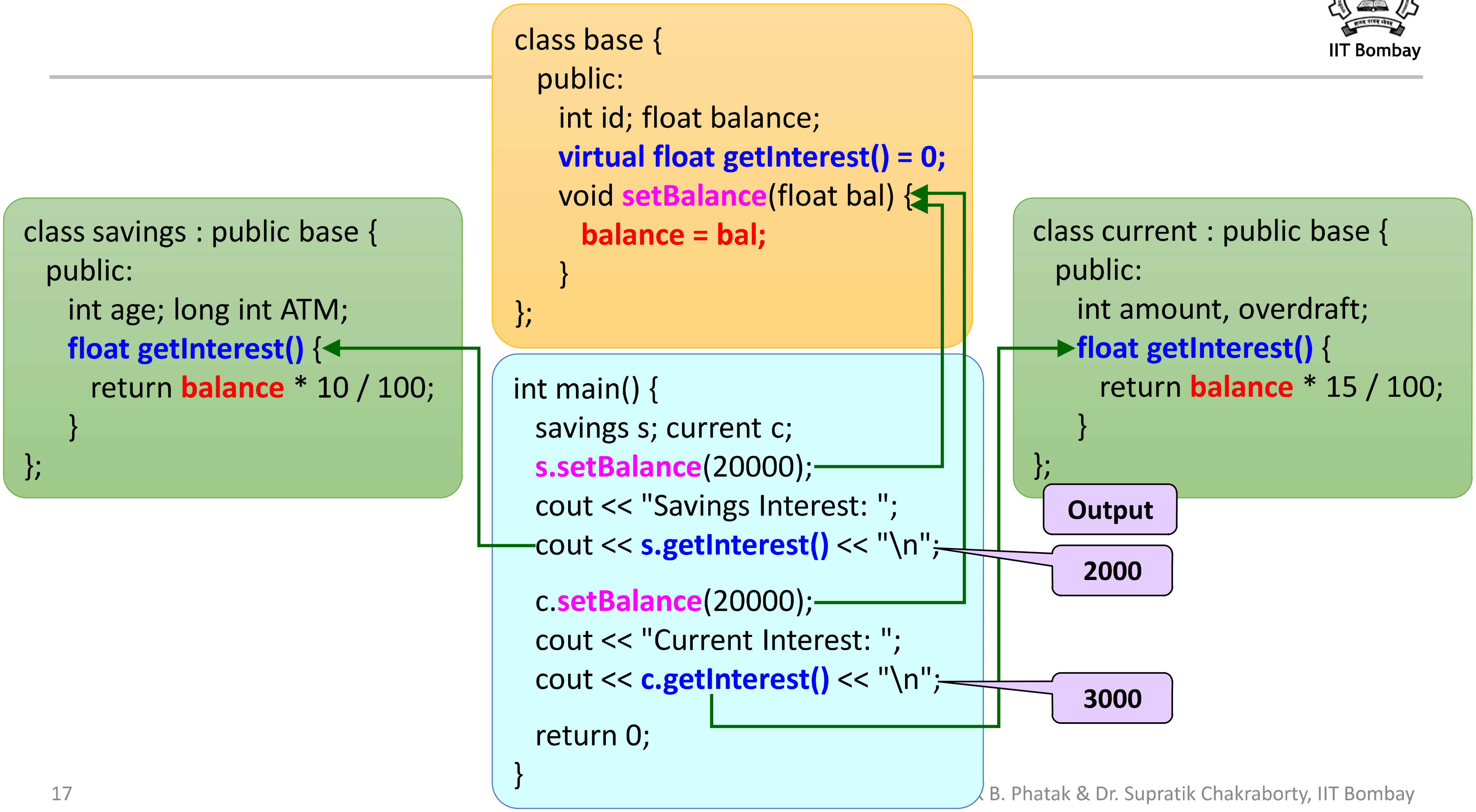
assigning 'current' object to 'base' pointer

print info from the 'current' object

Output

```
savings call
savings
current call
current
```

Abstract class: Example 2



```
class base {
  public:
    int id; float balance;
    virtual float getInterest() = 0;
    void setBalance(float bal) {
      balance = bal;
    }
};
```

```
class savings : public base {
  public:
    int age; long int ATM;
    float getInterest() {
      return balance * 10 / 100;
    }
};
```

```
class current : public base {
  public:
    int amount, overdraft;
    float getInterest() {
      return balance * 15 / 100;
    }
};
```

```
int main() {
  savings s; current c;
  s.setBalance(20000);
  cout << "Savings Interest: ";
  cout << s.getInterest() << "\n";

  c.setBalance(20000);
  cout << "Current Interest: ";
  cout << c.getInterest() << "\n";

  return 0;
}
```

Output

2000

3000

Abstract class

- Used when base class is only meant for derivation
- Helps in readability and understanding
- Prevents accidental instantiation of abstract class

Caveat: You cannot instantiate objects of this class

Summary

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- Polymorphism in C++ programming
- Virtual destructor
- Abstract class