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Polymorphism



C++ Object Oriented Programming

Pei-yih Ting

NTOU CS

Contents

- ✧ Assignment to base / derived types of objects
- ✧ Assignment to base / derived types of pointers

Contents

- ❖ Assignment to base / derived types of objects
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- ❖ Heterogeneous container and virtual functions

Contents

- ❖ Assignment to base / derived types of objects
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- ❖ Compile-time binding vs. run-time binding

Contents

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Contents

- ❖ Assignment to base / derived types of objects
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- ❖ Assignment to base / derived types of objects
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Contents

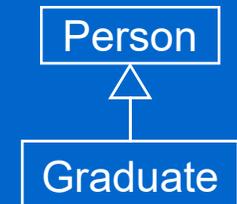
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- ❖ Double dispatch / Visitor Pattern

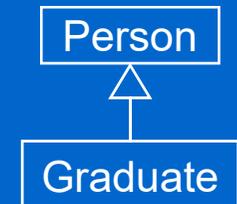
Assignment to Base Class Object

- ✧ Assume Graduate is derived from Person



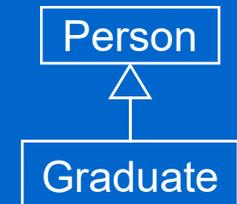
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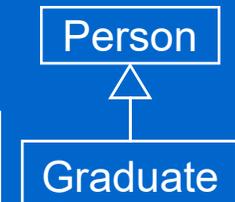
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Output:

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Joe is 19 years old.
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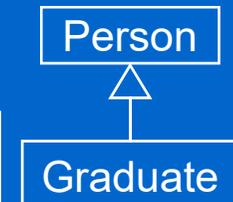
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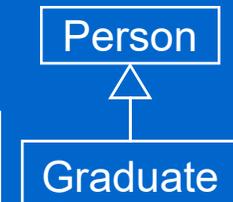
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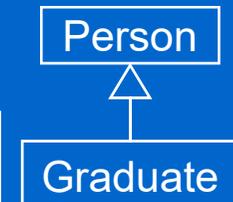
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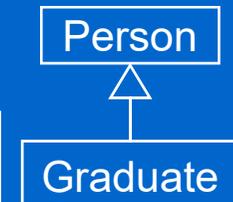
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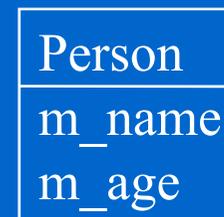
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- ❖ What happened:

1. A derived object, by definition, contains everything the base class has plus some extra elements.



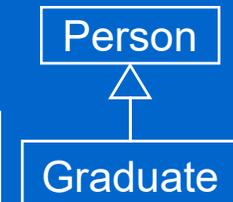
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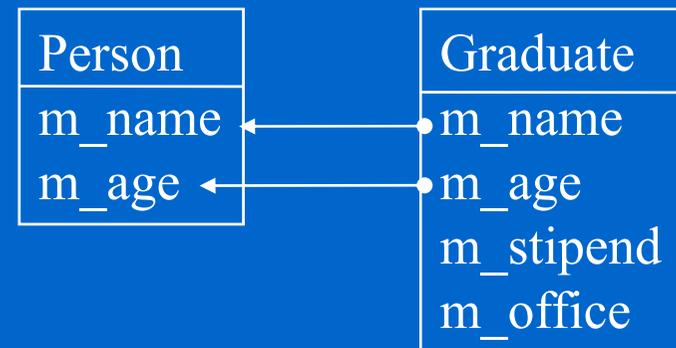
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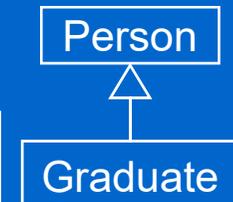
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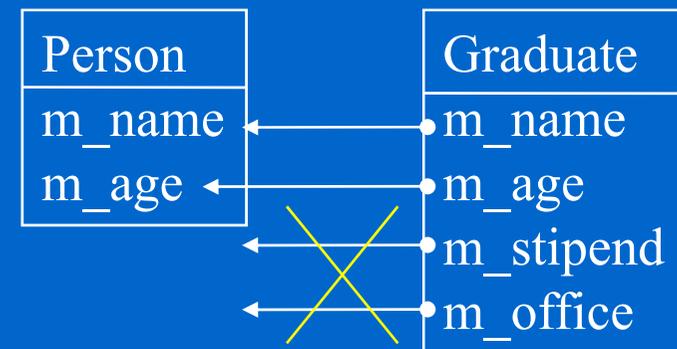
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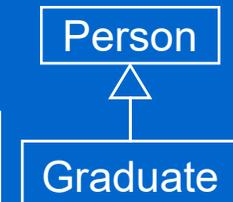
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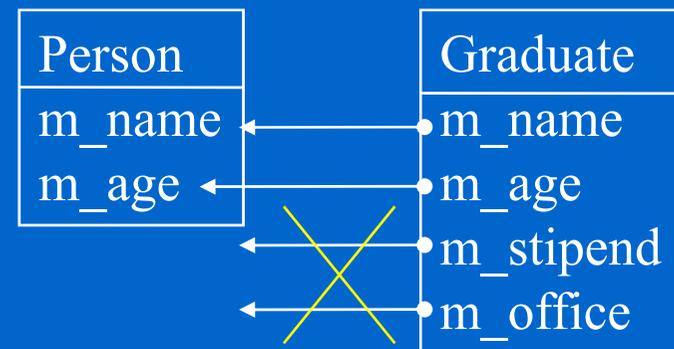
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Output:

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Joe is 19 years old.
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```



- ❖ What happened:
  1. A derived object, by definition, contains everything the base class has plus some extra elements.
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- ❖ If the **base class** has implemented the assignment operator or the copy ctor, they will be called.



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graduate = person; // assignment
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|           |
|-----------|
| Graduate  |
| m_name    |
| m_age     |
| m_stipend |
| m_office  |

|        |
|--------|
| Person |
| m_name |
| m_age  |

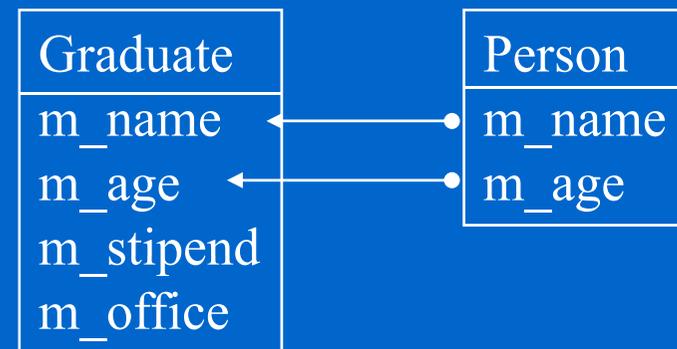
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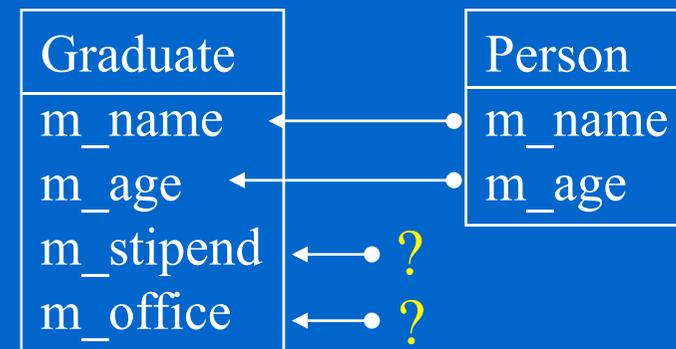
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The extra fields in the derived class would become uninitialized.



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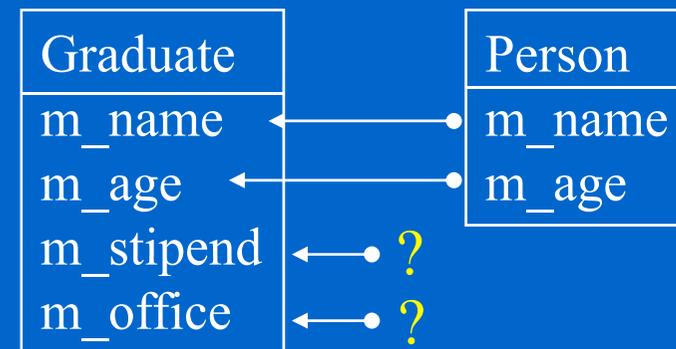
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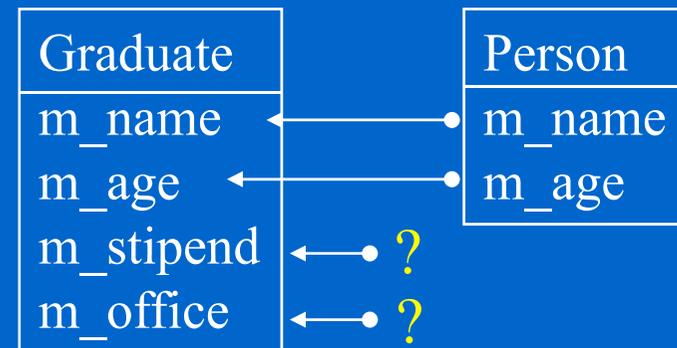
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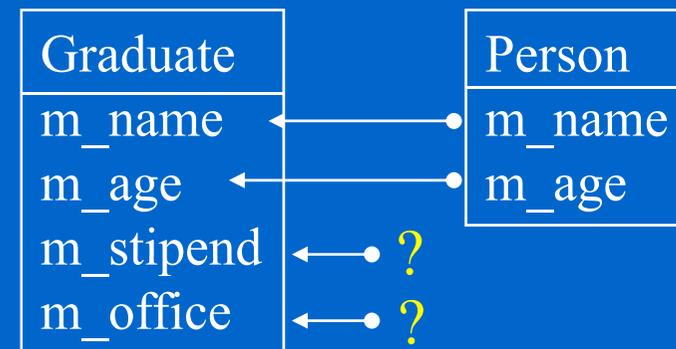
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- Summary**

“**derived** to **base**” only loses data (allowed).

“**base** to **derived**” leaves state undefined (forbidden).

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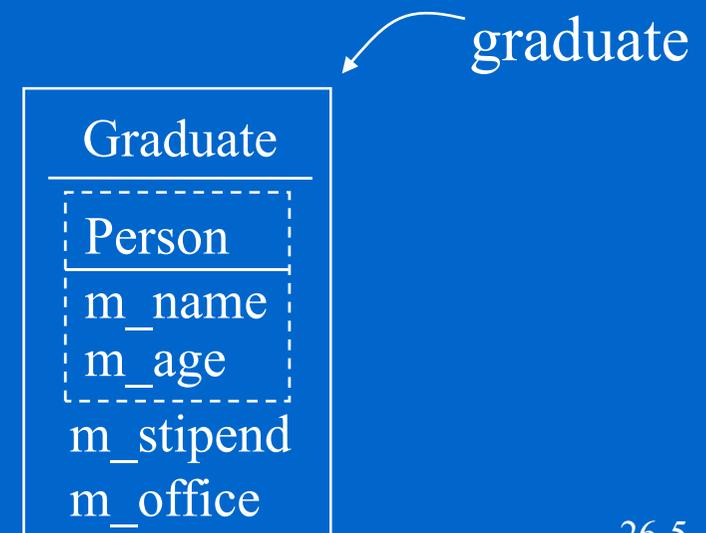
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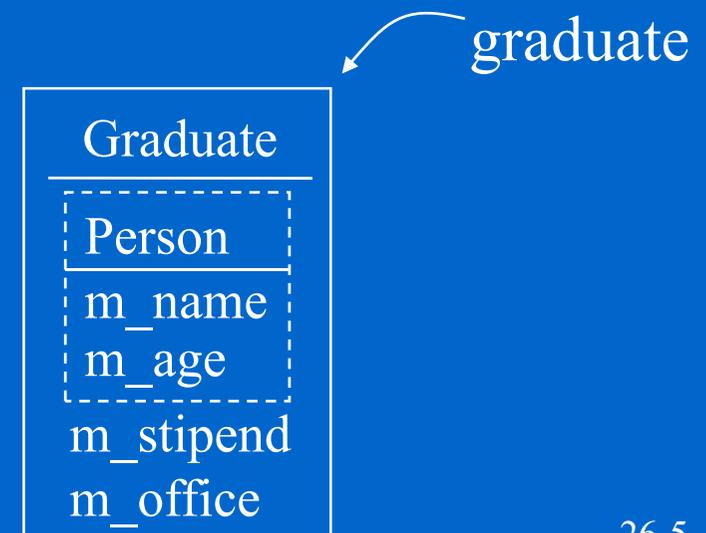
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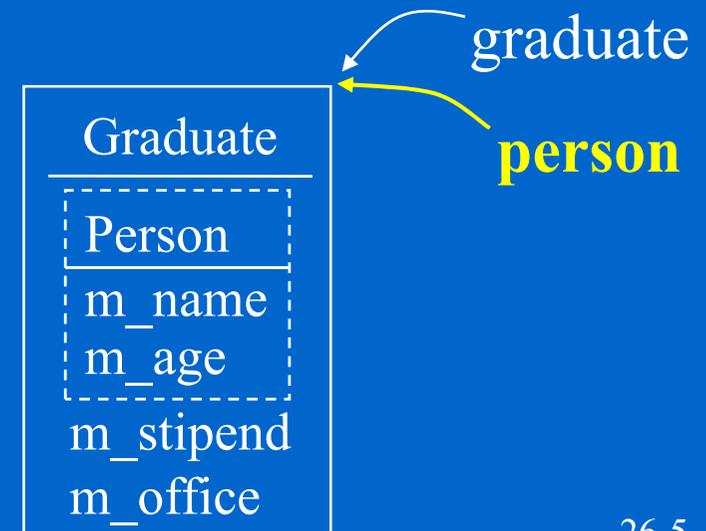
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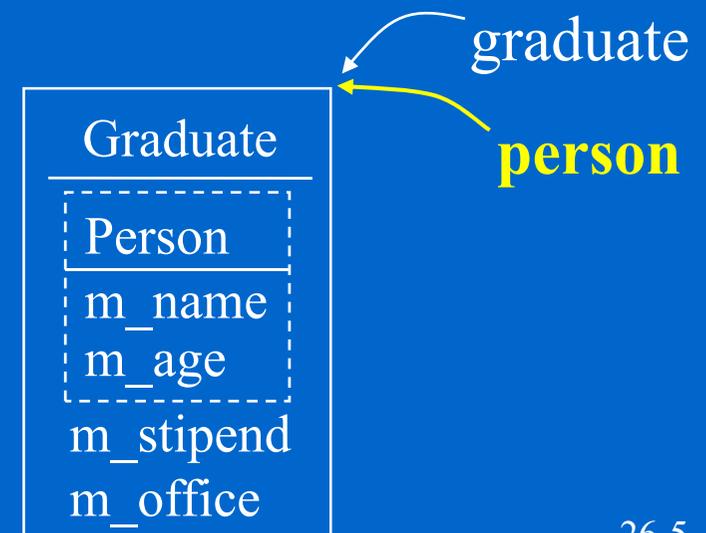
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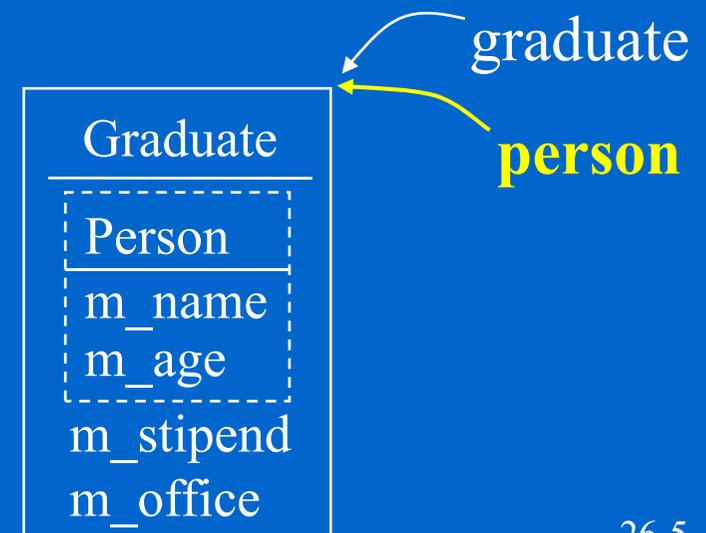
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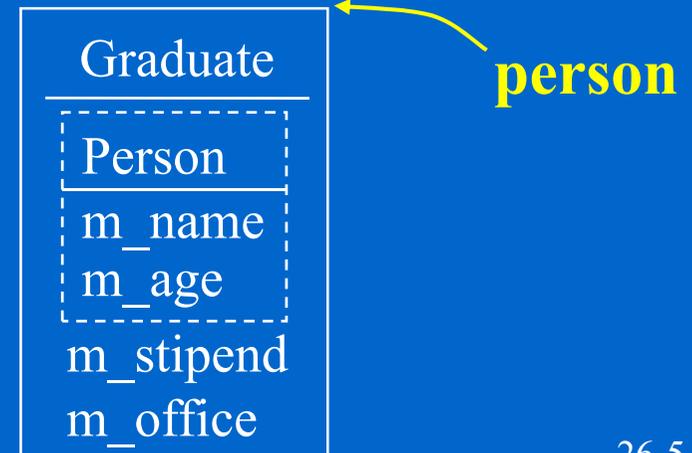
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1. `person->display()` calls `Person::display()` that shows the private data of the base part of either *Person* or *Graduate* object



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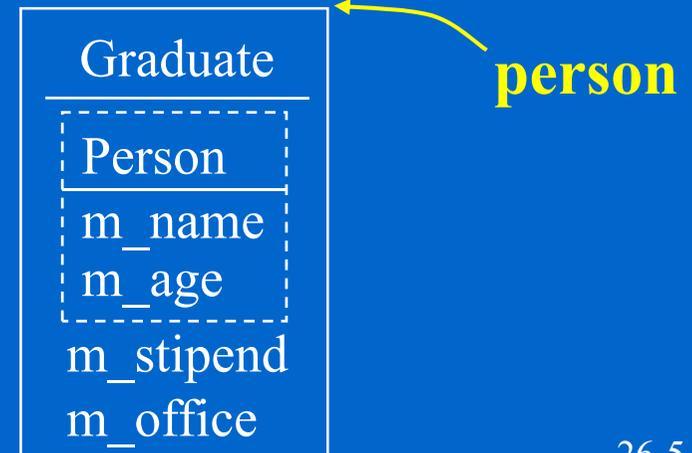
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1. `person->display()` calls `Person::display()` that shows the private data of the base part of either *Person* or *Graduate* object

2. `Person::display()` cannot access `Graduate::m_stipend` and `Graduate::m_office`



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## Output

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His address is 324rekj8

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Downcast is dangerous. It is correct only when the object pointed by *person* is an object of class Graduate.

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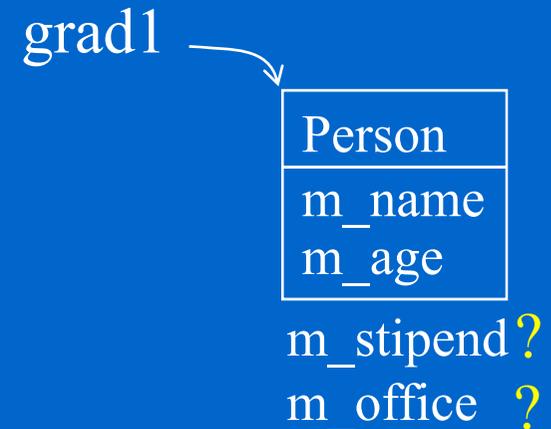
## Output

```
Joe is 19 years old.
He is a graduate student.
He has a stipend of -384584985 dollars.
His address is 324rekj8
```

- This is called a **downcast**.  
Downcast is dangerous. It is correct only when the object pointed by *person* is an object of class Graduate.

- What happened:

```
ex. person = grad2;
...
grad1 = (Graduate *) person;
```



# Assignment to Derived Class Pointer

- Assignment from a **base** pointer to a **derived** pointer is **evil**, but you certainly can coerce it with an explicit type cast

```
Person *person = new Person("Joe", 19);
Graduate *grad1, *grad2=new Graduate("Michael", 24, 6000, "INS501");
grad1 = (Graduate *) person;
grad1->display();
```

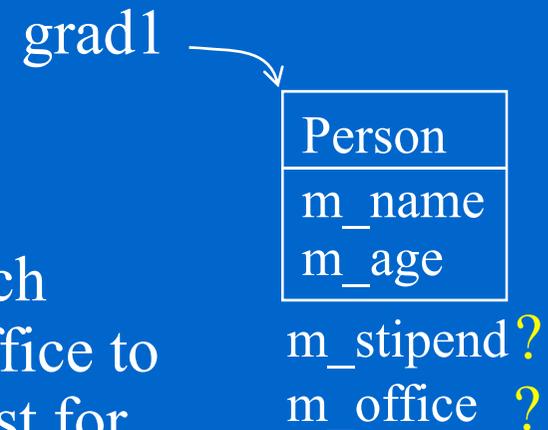
## Output

```
Joe is 19 years old.
He is a graduate student.
He has a stipend of -384584985 dollars.
His address is 324rekj8
```

- This is called a **downcast**.  
Downcast is dangerous. It is correct only when the object pointed by *person* is an object of class Graduate.

```
ex. person = grad2;
...
grad1 = (Graduate *) person;
```

- What happened:  
grad1->display() calls **Graduate::display()**, which accesses m\_name, m\_age, m\_stipend, and m\_office to display them, but the latter two fields do not exist for a Person object



# Assignment to Derived Class Pointer

- Assignment from a **base** pointer to a **derived** pointer is **evil**, but you certainly can coerce it with an explicit type cast

```
Person *person = new Person("Joe", 19);
Graduate *grad1, *grad2=new Graduate("Michael", 24, 6000, "INS501");
grad1 = (Graduate *) person;
grad1->display();
```

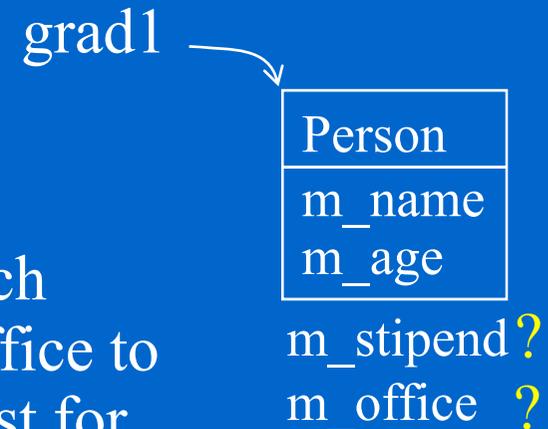
## Output

```
Joe is 19 years old.
He is a graduate student.
He has a stipend of -384584985 dollars.
His address is 324rekj8
```

- This is called a **downcast**.  
Downcast is dangerous. It is correct only when the object pointed by *person* is an object of class Graduate.

```
ex. person = grad2;
...
grad1 = (Graduate *) person;
```

- What happened:  
grad1->display() calls **Graduate::display()**, which accesses `m_name`, `m_age`, `m_stipend`, and `m_office` to display them, but the latter two fields do not exist for a Person object `grad1=dynamic_cast<Graduate *> person; //grad1 will be 0`



# Heterogeneous Container

- ✧ We would like to store all types of objects in a single database/array.

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Person *database[3];
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database[0] = new Undergraduate("Bob", 18);
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```
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```

```
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for (int i=0; i<3; i++)
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```
 database[i]->display();
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Output:



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Output:

```
Bob is 18 years old.
```

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for (int i=0; i<3; i++)
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 database[i]->display();
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Bob is 18 years old.
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```
Michael is 25 years old.
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for (int i=0; i<3; i++)
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```
 database[i]->display();
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Output:

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```
for (int i=0; i<3; i++)
```

```
 database[i]->display(); ←
```

- ✧ What is called by the above code is always **Person::display()**

Output:

Bob is 18 years old.

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```
for (int i=0; i<3; i++)
```

```
 database[i]->display(); <-----
```

Output:

```
Bob is 18 years old.
```

```
Michael is 25 years old.
```

```
Ron is 34 years old.
```

- ✧ What is called by the above code is always **Person::display()** which shows only the base part of each object

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 database[i]->display(); <-----
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Output:

```
Bob is 18 years old.
```

```
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```

```
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```

- ❖ What is called by the above code is always **Person::display()** which shows only the base part of each object instead of the **display()** of a derived class which shows all detail information of the derived class.

# Heterogeneous Container

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```
for (int i=0; i<3; i++)
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 database[i]->display(); <-----
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Output:

```
Bob is 18 years old.
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- ✧ What is called by the above code is always **Person::display()** which shows only the base part of each object instead of the **display()** of a derived class which shows all detail information of the derived class.

Note: in the above program, we can use static object array **Person database[3];** as well, the printed results would be the same, but what it really saved **differ**.

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```
for (int i=0; i<3; i++)
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```
 database[i]->display(); <-----
```

Output:

```
Bob is 18 years old.
```

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Michael is 25 years old.
```

```
Ron is 34 years old.
```

- ❖ What is called by the above code is always **Person::display()** which shows only the base part of each object instead of the **display()** of a derived class which shows all detail information of the derived class.

Note: in the above program, we can use static object array **Person database[3];** as well, the printed results would be the same, but what it really saved **differ**.

- ❖ Is there a way that can make the above code display all detail information of every derived class in a uniform way?

# A Solution with Data Tag

- ❖ Create an enumerated type for each base type:

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enum ObjectType {undergrad, grad, professor};
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```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();

 void display() const;
private:
 char *m_name;
 int m_age;

};
```

# A Solution with Data Tag

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 Person();
 Person(char *name, int age);
 ~Person();

 void display() const;
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 char *m_name;
 int m_age;
 ObjectType m_typeTag;
};
```

# A Solution with Data Tag

- ❖ Create an enumerated type for each base type:

```
enum ObjectType {undergrad, grad, professor};
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```
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public:
 Person();
 Person(char *name, int age, ObjectType typeTag);
 ~Person();

 void display() const;
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 char *m_name;
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# A Solution with Data Tag

- ❖ Create an enumerated type for each base type:

```
enum ObjectType {undergrad, grad, professor};
```

- ❖ Add a tag of this type to the base class

```
class Person {
public:
 Person();
 Person(char *name, int age, ObjectType typeTag);
 ~Person();
 ObjectType getType();
 void display() const;
private:
 char *m_name;
 int m_age;
 ObjectType m_typeTag;
};
```

# A Solution with Data Tag

- ❖ Create an enumerated type for each base type:

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 char *m_name;
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 ObjectType m_typeTag;
};
```

```
Undergraduate::Undergraduate(...):
 Person(...,undergrad)
{...}
```

# A Solution with Data Tag

- ❖ Create an enumerated type for each base type:

```
enum ObjectType {undergrad, grad, professor};
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- ❖ Make the necessary changes in the constructor

# A Solution with Data Tag

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enum ObjectType {undergrad, grad, professor};
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 Person(char *name, int age, ObjectType typeTag);
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 void display() const;
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 char *m_name;
 int m_age;
 ObjectType m_typeTag;
};
```

```
Undergraduate::Undergraduate(...):
 Person(...,undergrad)
{...}
```

- ❖ Make the necessary changes in the constructor

```
Person::Person(char *name, int age, ObjectType typeTag)
 : m_age(age), m_typeTag(typeTag) {
 m_name = new char[strlen(name)+1];
 strcpy(m_name, name);
}
```

# A Solution with Data Tag (Cont'd)

```
Person *database[3], *temp;
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
database[2] = new Faculty("Ron", 34, "Gates 199", "associate professor");
```

# A Solution with Data Tag (Cont'd)

```
Person *database[3], *temp;
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
database[2] = new Faculty("Ron", 34, "Gates 199", "associate professor");
for (int i=0; i<3; i++) {

}
```

# A Solution with Data Tag (Cont'd)

```
Person *database[3], *temp;
database[0] = new Undergraduate("Bob", 18);
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database[2] = new Faculty("Ron", 34, "Gates 199", "associate professor");
for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {

}
}
```

# A Solution with Data Tag (Cont'd)

```
Person *database[3], *temp;
database[0] = new Undergraduate("Bob", 18);
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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;

 }
}
```

# A Solution with Data Tag (Cont'd)

```
Person *database[3], *temp;
database[0] = new Undergraduate("Bob", 18);
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 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 }
}
```

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```
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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
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 }
}
```

# A Solution with Data Tag (Cont'd)

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 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
 break;
 }
}
```

Using code to select code

# A Solution with Data Tag (Cont'd)

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Person *database[3], *temp;
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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
 break;
 }
}
```

evil

Downcast is the  
“goto” for OOP!!

Using code to select code

# A Solution with Data Tag (Cont'd)

```
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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
 break;
 }
}
```

evil

Downcast is the  
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Using code to select code

This is a segment of code not satisfying **open-closed principle**.

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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
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 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
 break;
 }
}
```

evil

Downcast is the  
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Using code to select code

This is a segment of code not satisfying **open-closed principle**.  
Usually, this is avoided with the “**strategy**” pattern.

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for (int i=0; i<3; i++) {
 temp = database[i];
 switch (temp->getType()) {
 case undergrad:
 ((Undergraduate *) temp)->display();
 break;
 case grad:
 ((Graduate *) temp)->display();
 break;
 case professor:
 ((Faculty *) temp)->display();
 break;
 }
}
```

evil

Downcast is the  
“goto” for OOP!!

Using code to select code

another way to implement w/o tags

```
// RTTI
if (dynamic_cast<Undergraduate*>(temp))
 ((Undergraduate*)temp)->display();
else if (dynamic_cast<Graduate*>(temp))
 ((Graduate*)temp)->display();
else if (dynamic_cast<Faculty*>(temp))
 ((Faculty*)temp)->display();
```

This is a segment of code not satisfying **open-closed principle**.  
Usually, this is avoided with the “**strategy**” pattern.

# Solution with **Virtual Function**

- ① Declare the function as *virtual* in the **base class**

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```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();

private:
 char *m_name;
 int m_age;
};
```

# Solution with **Virtual Function**

- ① Declare the function as *virtual* in the **base class**

```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
private:
 char *m_name;
 int m_age;
};
```

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```

- ② Invoke indirectly through base class pointer or reference

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class Person {
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 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
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 char *m_name;
 int m_age;
};
```

- ② **Invoke indirectly through base class pointer or reference**

```
Person *database[3];
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
database[2] = new Faculty("Ron", 34, "INS512", "associate professor");
```

# Solution with **Virtual Function**

- ① Declare the function as **virtual** in the **base class**

```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
private:
 char *m_name;
 int m_age;
};
```

- ② **Invoke indirectly through base class pointer or reference**

```
Person *database[3];
database[0] = new Undergraduate("Bob", 18);
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for (int i=0; i<3; i++)
 database[i]->display();
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# Solution with **Virtual Function**

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class Person {
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 Person();
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Person *database[3];
database[0] = new Undergraduate("Bob", 18);
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for (int i=0; i<3; i++)
 database[i]->display();
```

or equivalently (\*database[i]).display();

# Solution with **Virtual Function**

- ① Declare the function as **virtual** in the **base class**

```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
private:
 char *m_name;
 int m_age;
};
```

Outputs

```
Bob is 18 years old.
He is an undergraduate.
```

- ② Invoke indirectly through base class pointer or reference

```
Person *database[3];
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
database[2] = new Faculty("Ron", 34, "INS512", "associate professor");
for (int i=0; i<3; i++)
 database[i]->display(); ←
```

Will invoke Undergraduate::display()

or equivalently (\*database[i]).display();

# Solution with **Virtual Function**

- ① Declare the function as **virtual** in the **base class**

```
class Person {
public:
 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
private:
 char *m_name;
 int m_age;
};
```

Outputs

```
Bob is 18 years old.
He is an undergraduate.
=====
Bob is 18 years old.
He is a graduate student.
He has a stipend of 6000 dollars.
His address is INS501.
```

- ② Invoke indirectly through base class pointer or reference

```
Person *database[3];
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
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for (int i=0; i<3; i++)
 database[i]->display(); ←
```

Will invoke Undergraduate::display(),  
Graduate::display()

or equivalently (\*database[i]).display();

# Solution with **Virtual Function**

- ① Declare the function as **virtual** in the **base class**

```
class Person {
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 Person();
 Person(char *name, int age);
 ~Person();
 virtual void display() const;
private:
 char *m_name;
 int m_age;
};
```

Outputs

```
Bob is 18 years old.
He is an undergraduate.

Bob is 18 years old.
He is a graduate student.
He has a stipend of 6000 dollars.
His address is INS501.

Ron is 34 years old.
His address is INS512.
His rank is associate professor.
```

- ② Invoke indirectly through **base class pointer** or **reference**

```
Person *database[3];
database[0] = new Undergraduate("Bob", 18);
database[1] = new Graduate("Michael", 25, 6000, "INS501");
database[2] = new Faculty("Ron", 34, "INS512", "associate professor");
for (int i=0; i<3; i++)
 database[i]->display(); ←
```

Will invoke Undergraduate::display(),  
Graduate::display(), and Faculty::display()  
in turn

or equivalently (\*database[i]).display();

# Virtual vs. Non-virtual Functions

```
Person *base = new Person("Bob", 18);
```

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Faculty *derived = new Faculty("Ron", 34, "INS512", "associate professor");
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## Nonvirtual function

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.....  
display()

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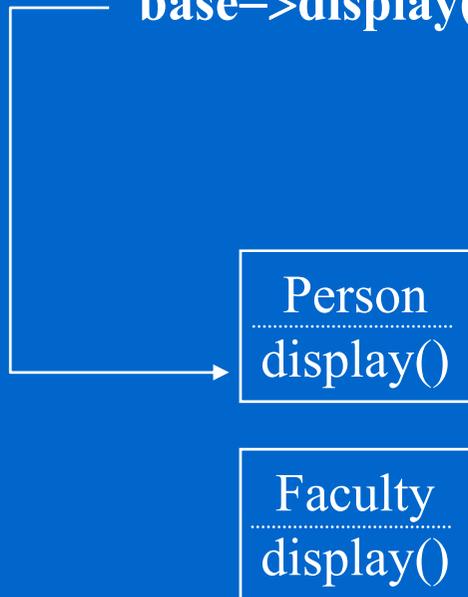
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base->display();
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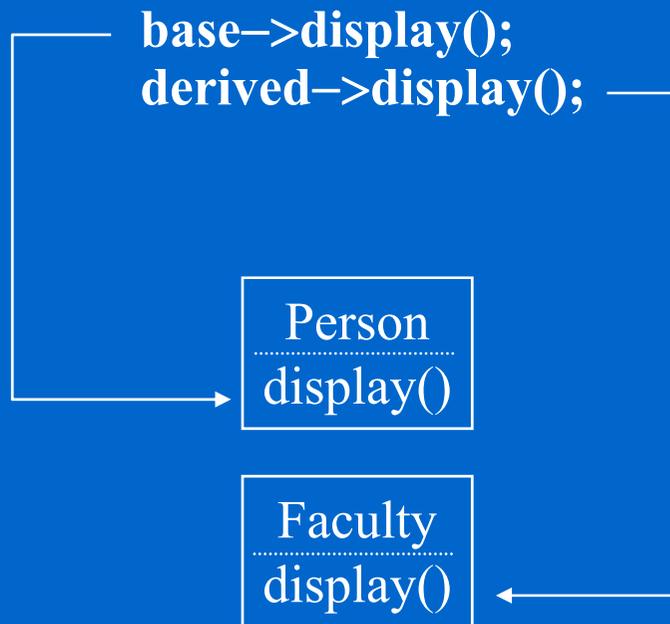


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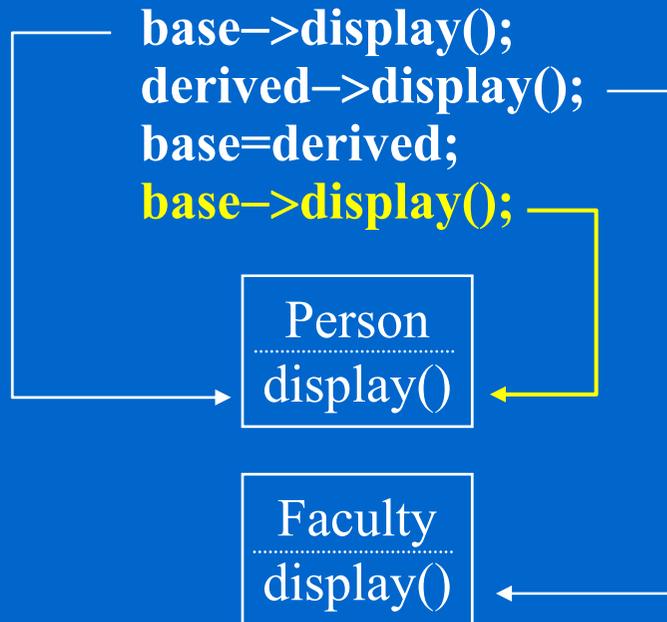


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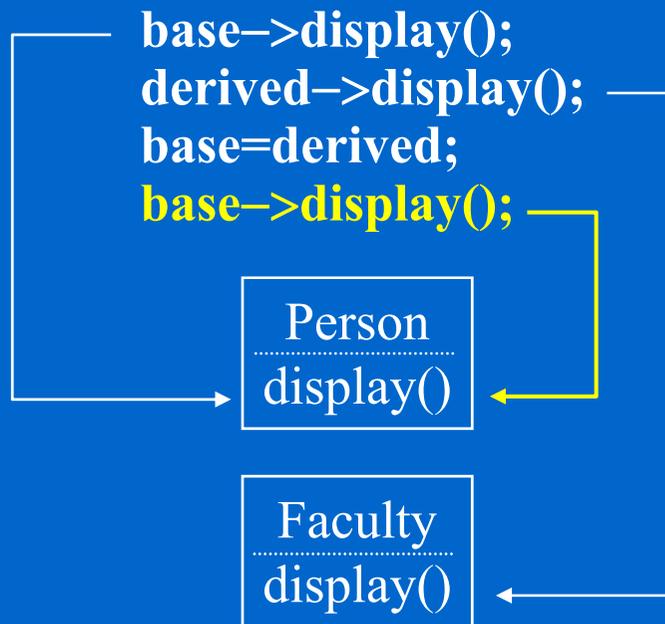


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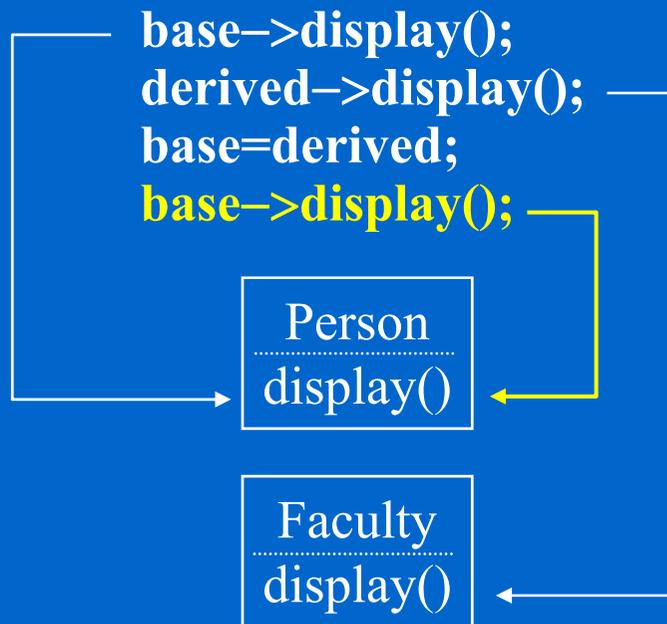
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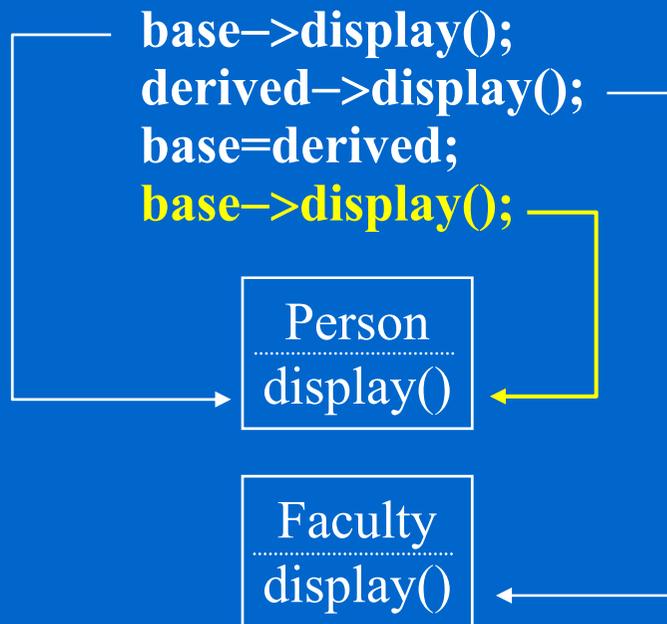
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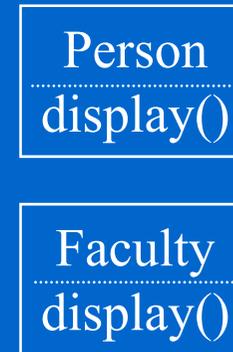
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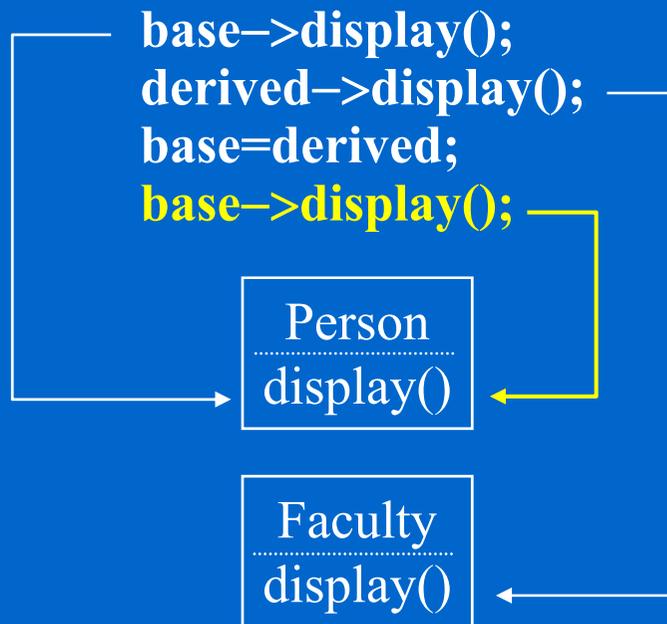


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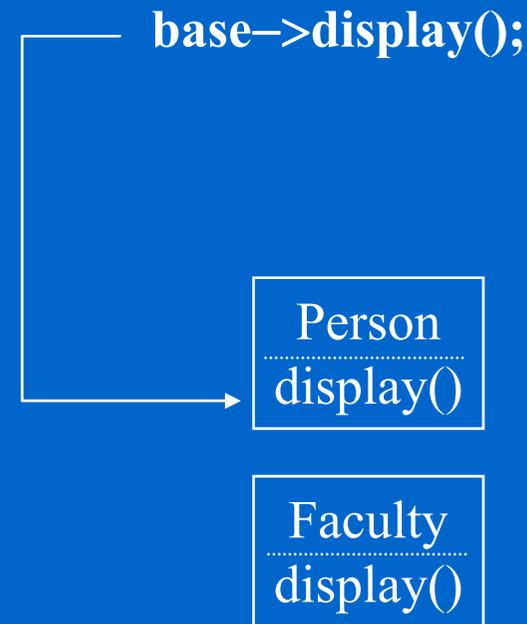
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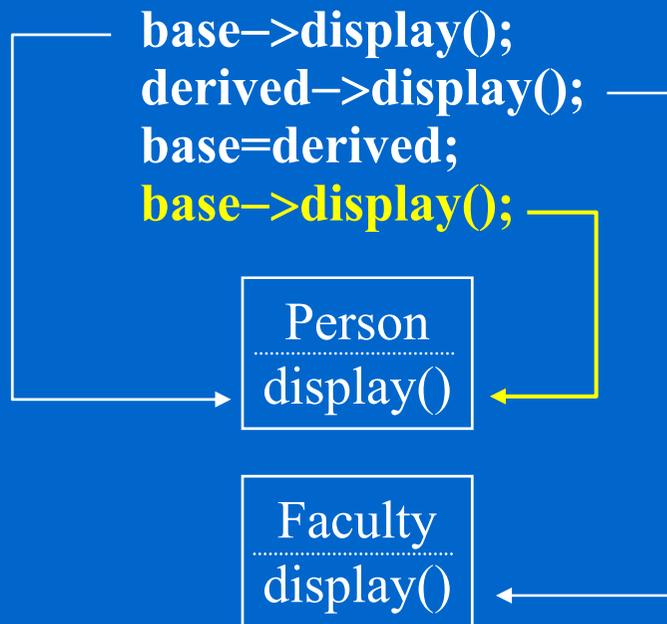


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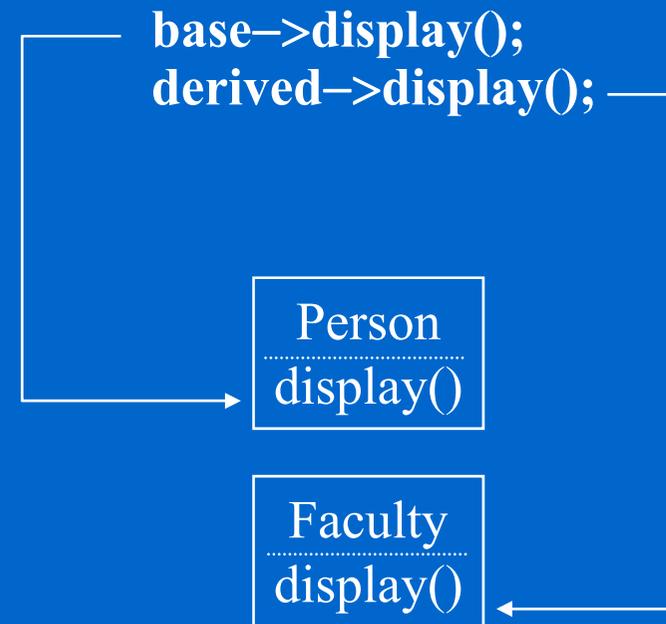
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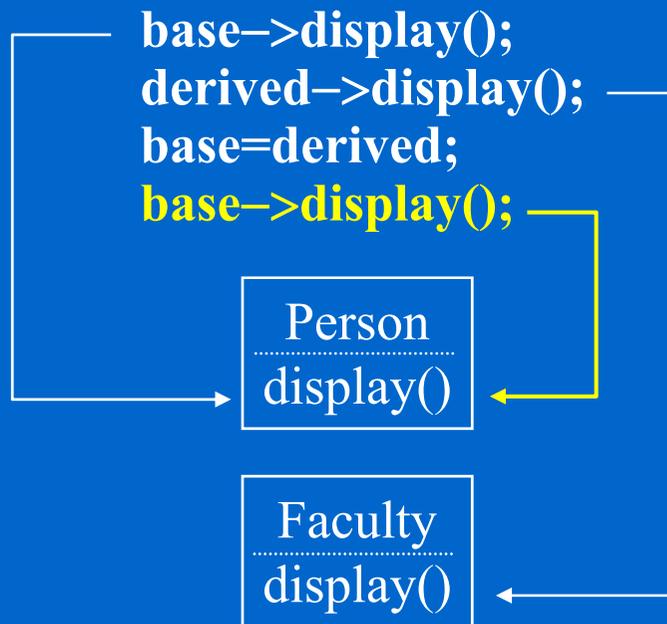


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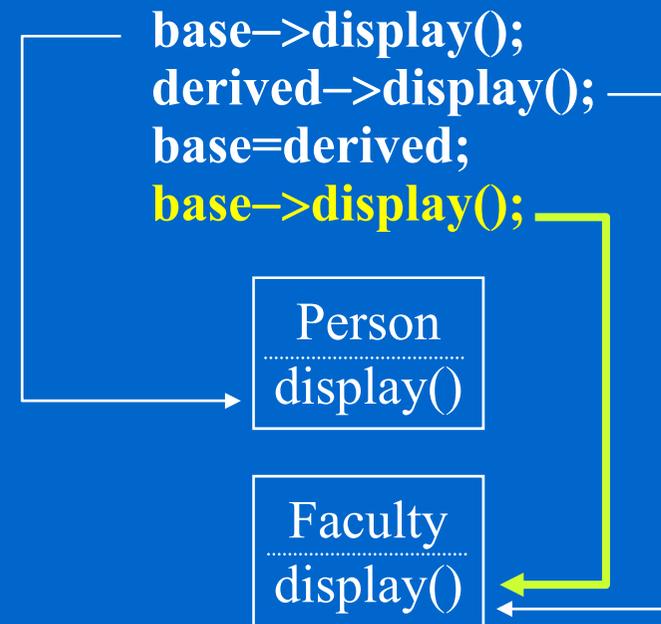
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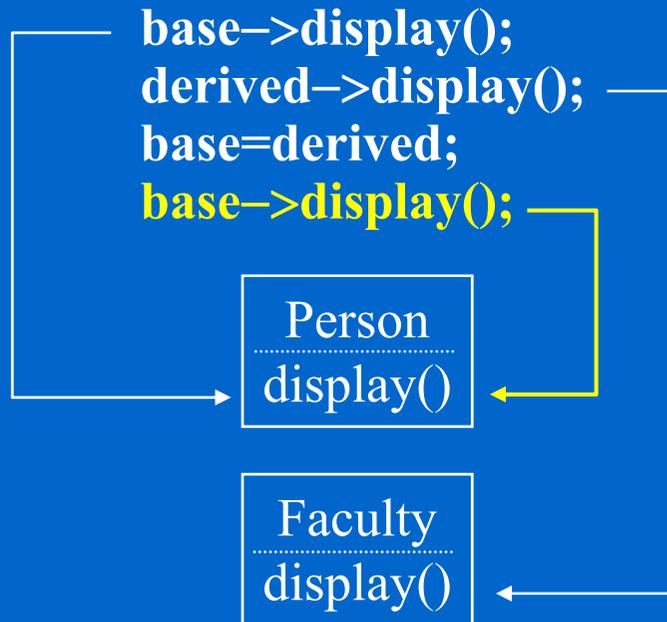


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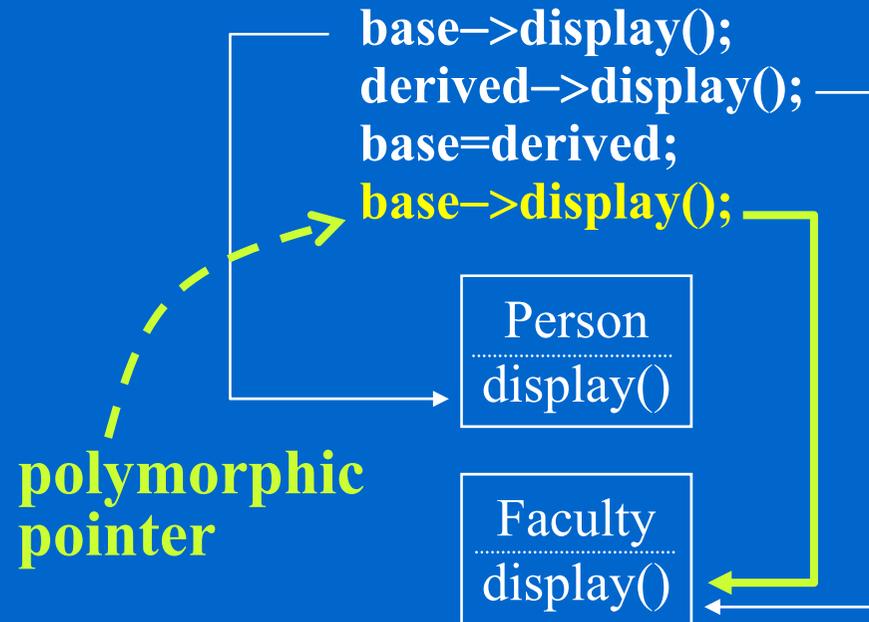
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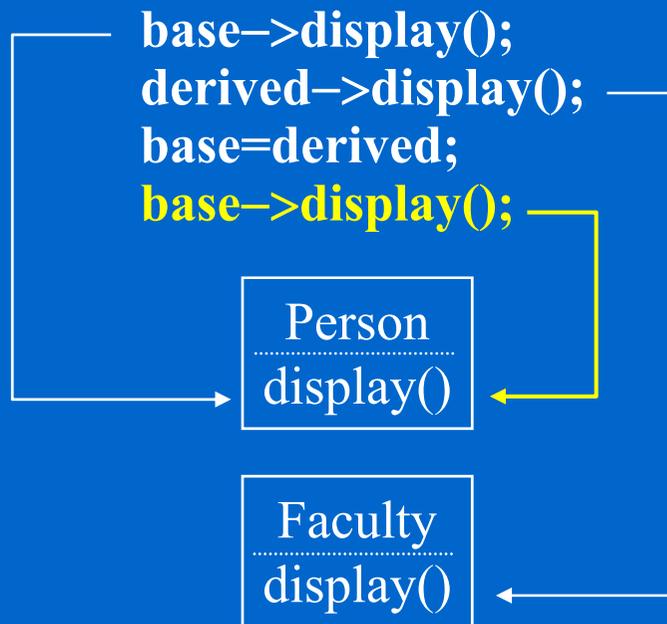


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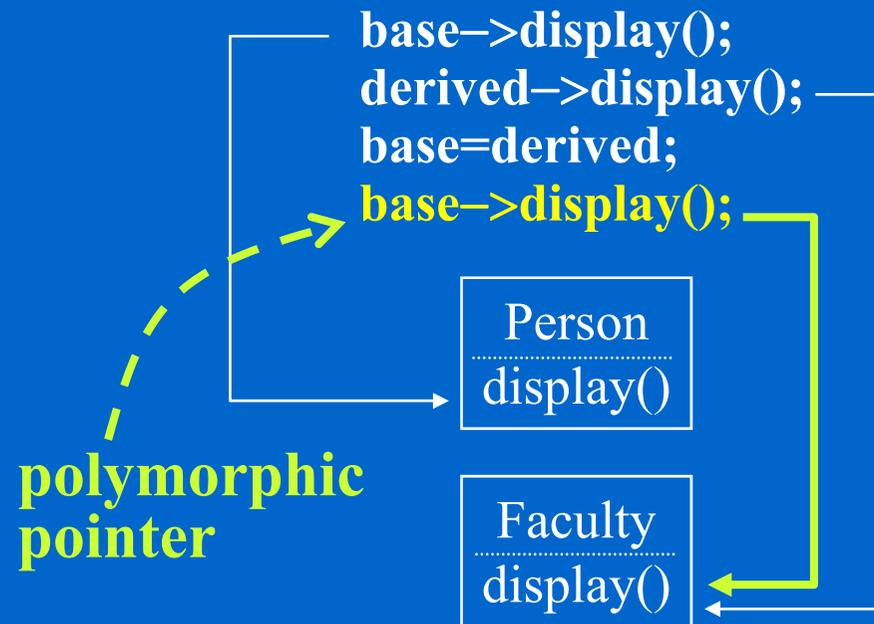
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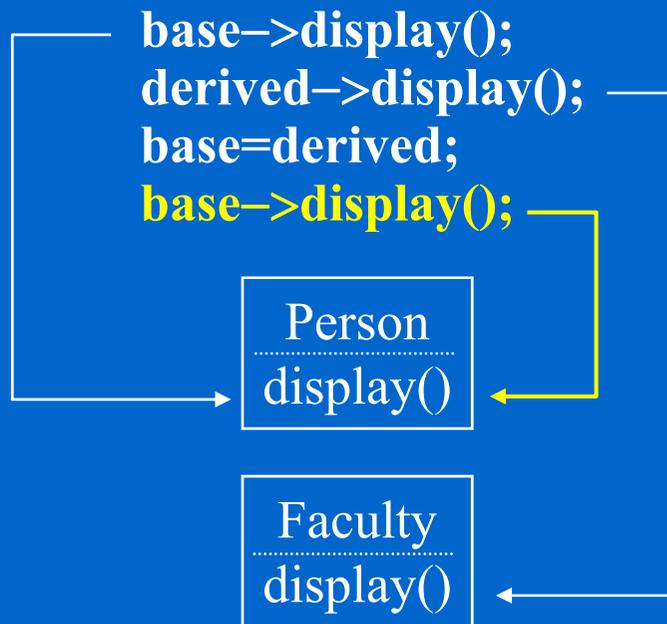
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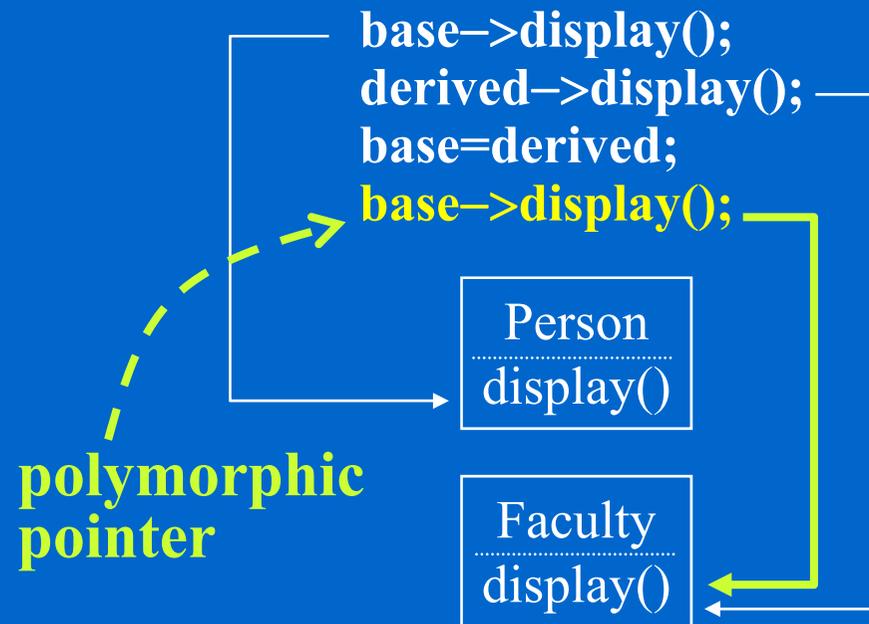
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The function to be called is determined by the **object the pointer refers to during run-time**.

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- ❖ **Static member functions** and **constructors** cannot be declared virtual. **Destructors** are always declared as virtual functions.

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```
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```

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|                                                                   |                                                                   |
|-------------------------------------------------------------------|-------------------------------------------------------------------|
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```
int (*fp)(int);
```

```
fp = func1;
```

```
(*fp)(123); // calling function func1(), i.e. func1(123)
```

# Function Pointer (cont'd)

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```
void service(int (*proc)(int), int data) {
 ...
 (*proc)(data);
 ...
}

...
fp = func2;

...
service(fp, x);
```

# Virtual Table

- ✧ C++ uses function pointers to implement the **late binding**

# Virtual Table

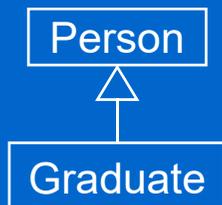
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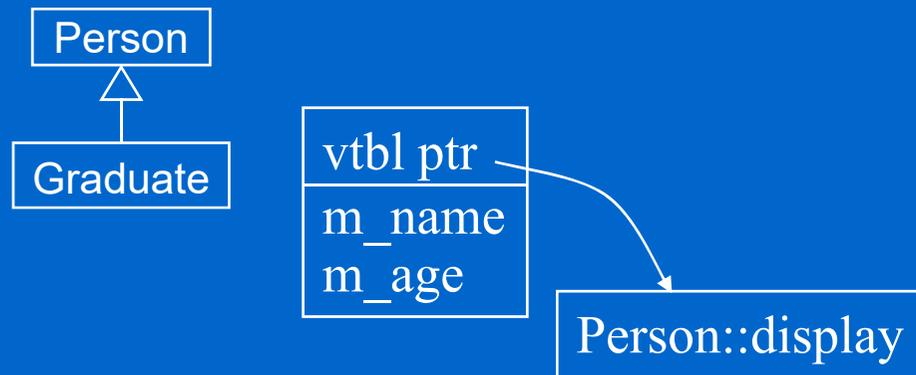
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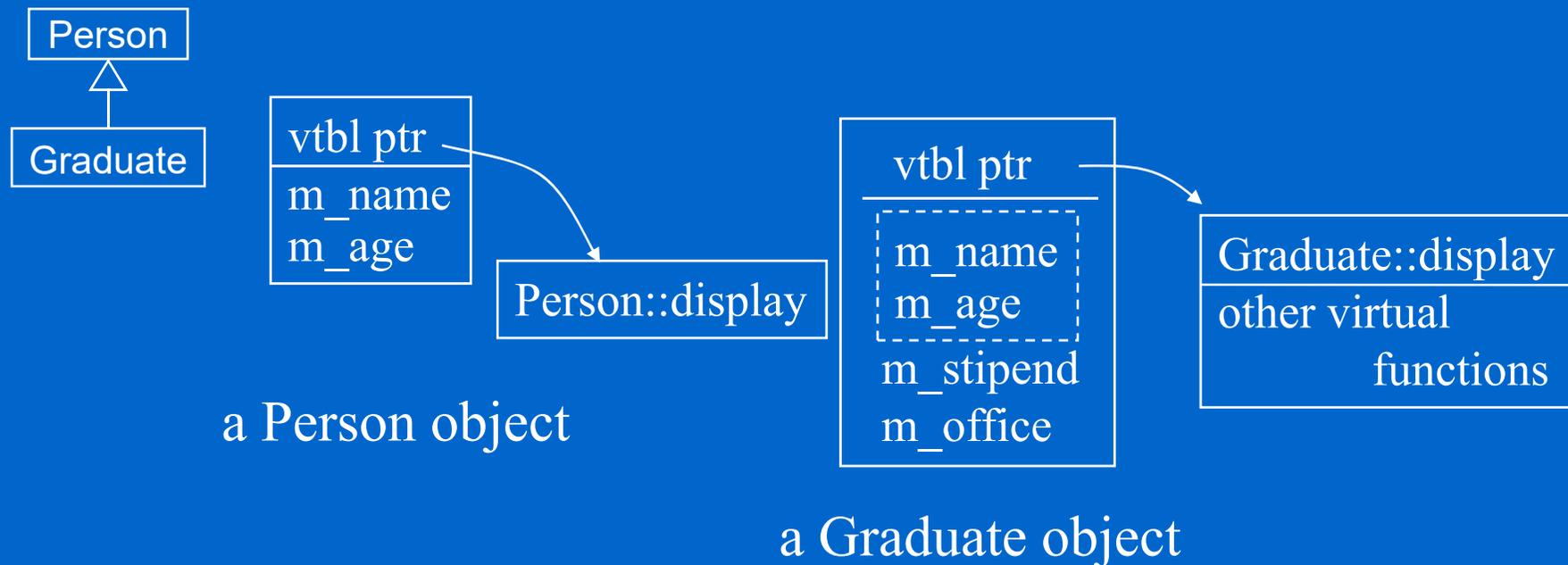
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a Person object

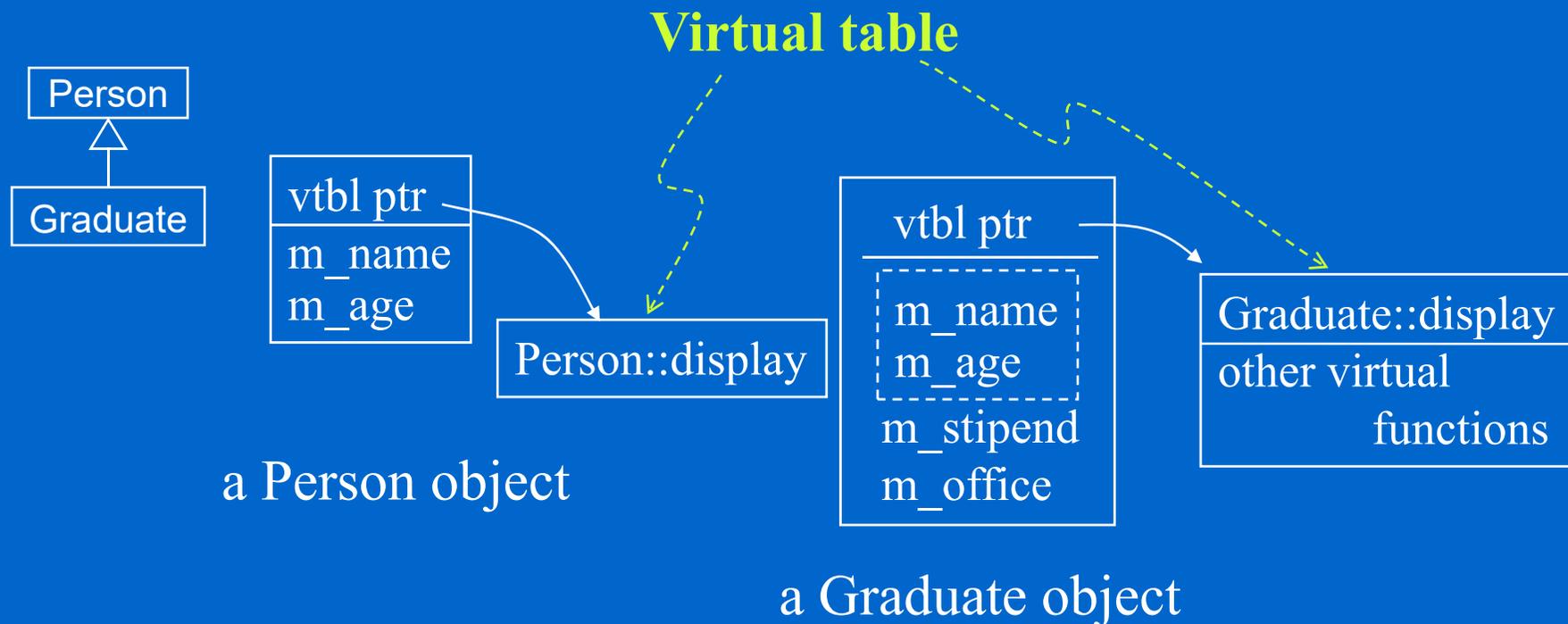
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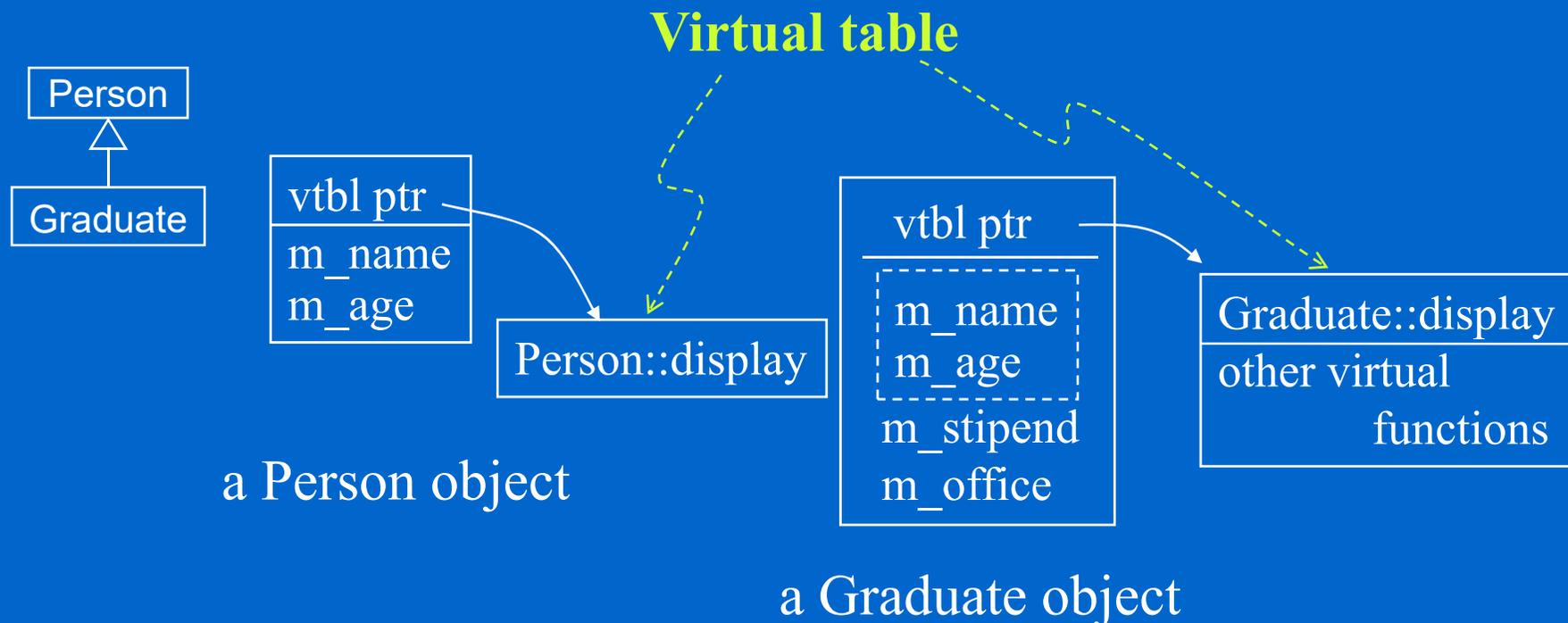
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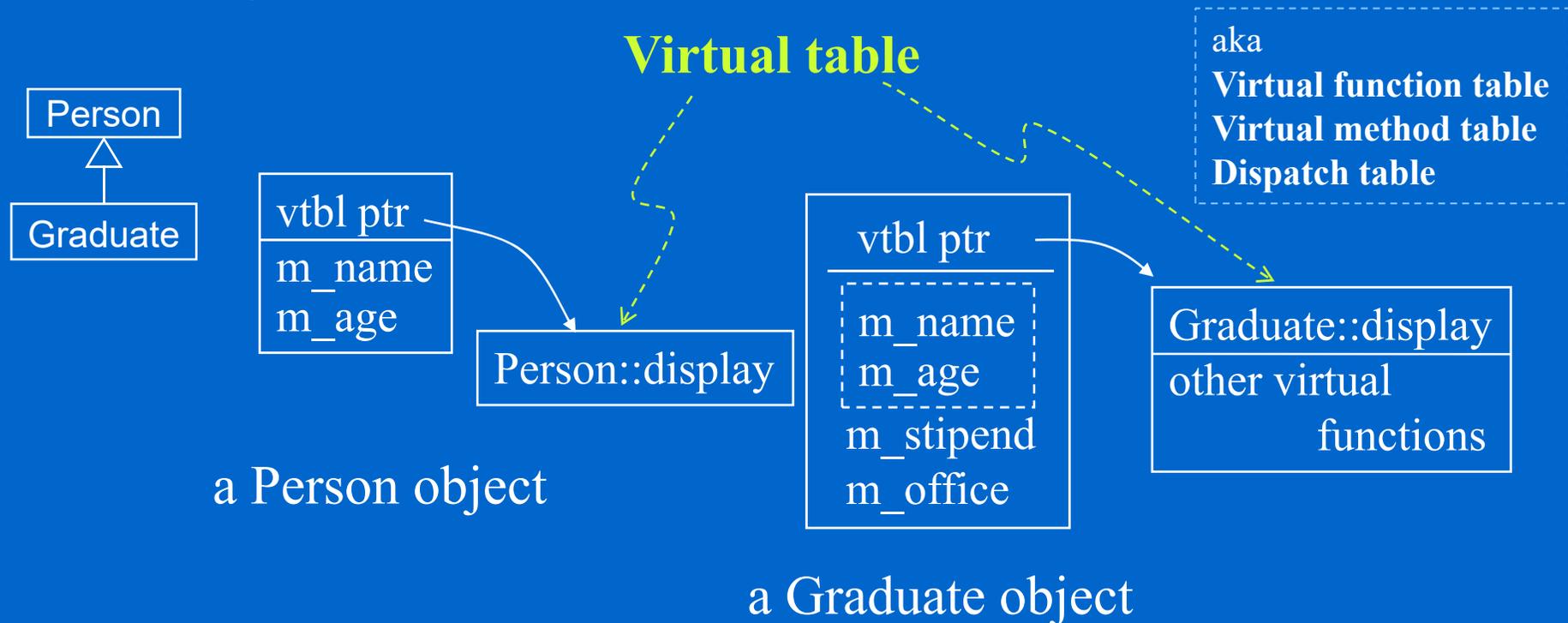
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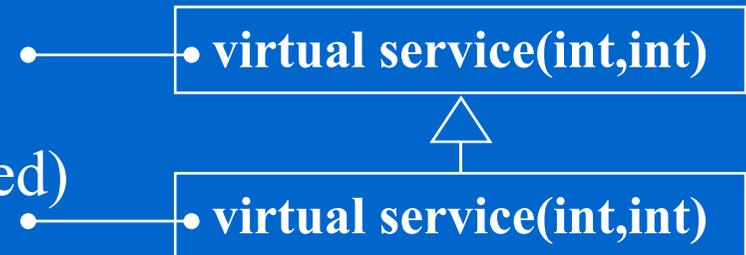
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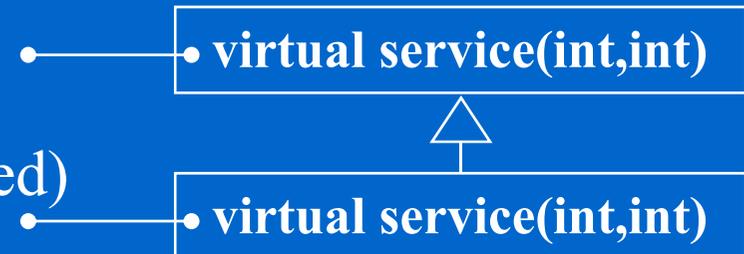


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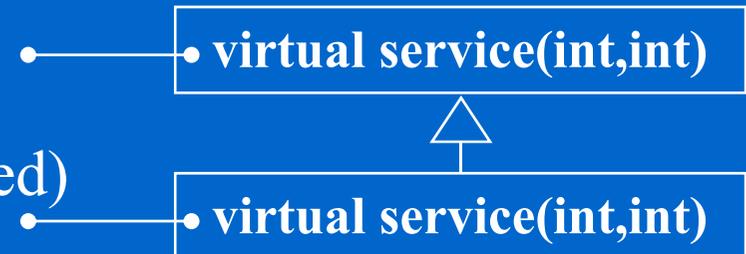
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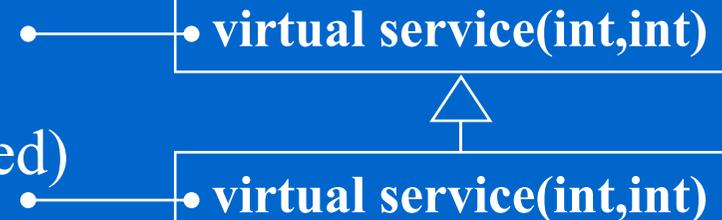
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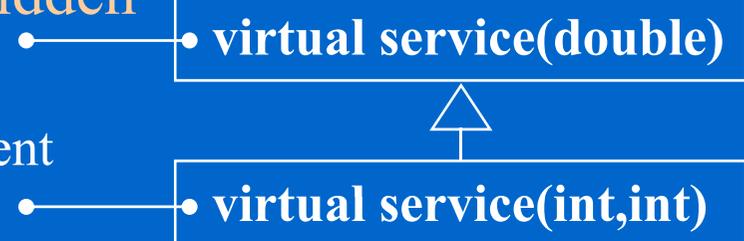


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2. When a base class declares a **non-virtual** member function and a derived class declares a member function **with** the same name but **with** or **without** the same signature.

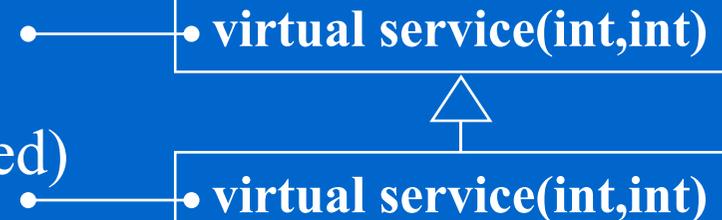
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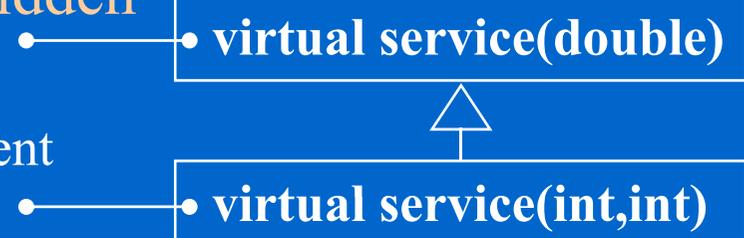


❖ **Overriding**: two functions in **different scopes** (parent vs **child**), have the same name. same signatures (**virtual** is required)

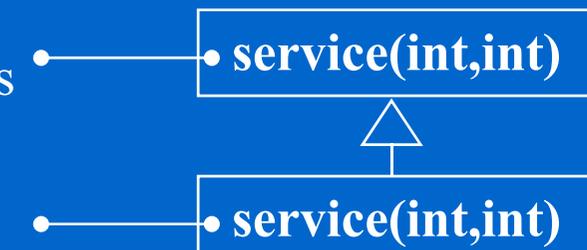


❖ **Hiding**: base class member function is hidden

1. When a base class and a derived class declare virtual member functions with different signatures but **with** the same name.



2. When a base class declares a **non-virtual** member function and a derived class declares a member function **with** the same name but **with** or **without** the same signature.



# Virtual Function vs. Overloading

# Virtual Function vs. Overloading

## ✧ Overloading

# Virtual Function vs. Overloading

✧ Overloading (**static** polymorphism or **compile-time** polymorphism)

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```
void Person::display() const;
void Person::display(bool showDetail) const;
```

The arguments of the overloaded functions must differ.

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virtual void Person::display() const;
virtual void Faculty::display() const;
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The arguments must be identical.

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★ In Faculty class, display(bool) does **NOT** *override* Person::display(),

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- ★ This phenomenon is called **hiding**.

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void Person::display() const;
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- ★ Only **Faculty::display(bool)** can be called with a Faculty object or pointer, no Faculty::display(), although **Person::display()** can also be called.

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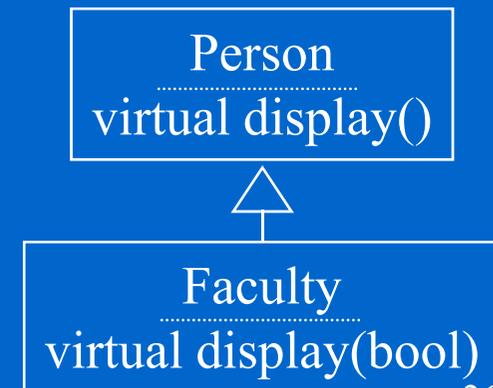
```
virtual void Person::display() const;
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```

```
Person::display()
Faculty::display()
Faculty::display(bool)
```

- ★ In Faculty class, display(bool) does **NOT** *override* Person::display(),
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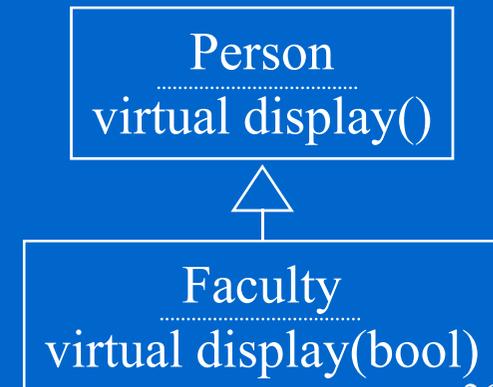
# Member Function Calling Rule

```
Faculty *prof = new Faculty("Ron", 34, "INS512", "associate professor");
Person *person = prof;
```



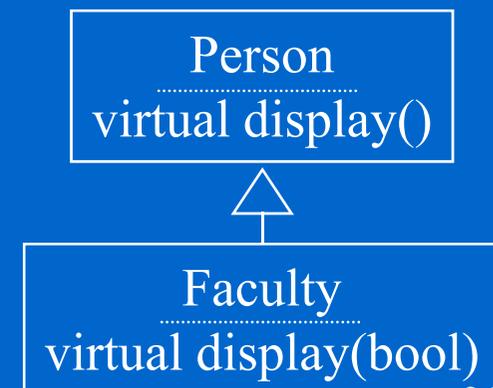
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Faculty *prof = new Faculty("Ron", 34, "INS512", "associate professor");
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person->display(); // dynamically binded, calling Person::display()
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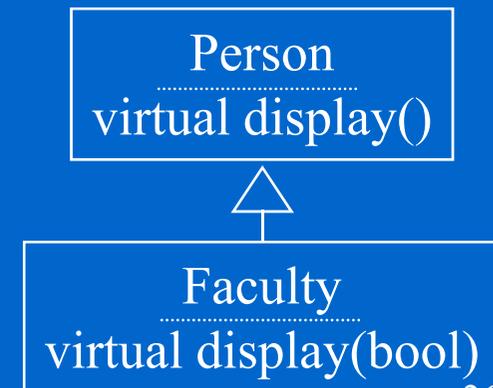
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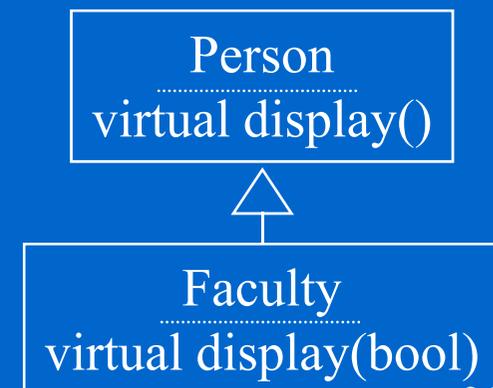
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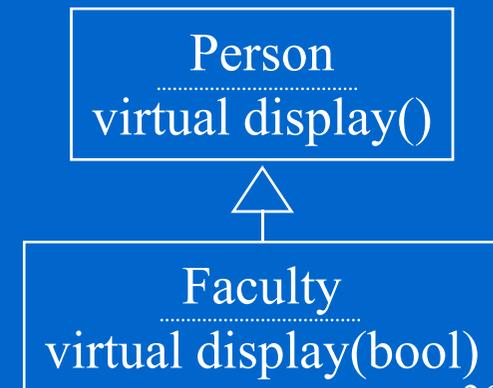
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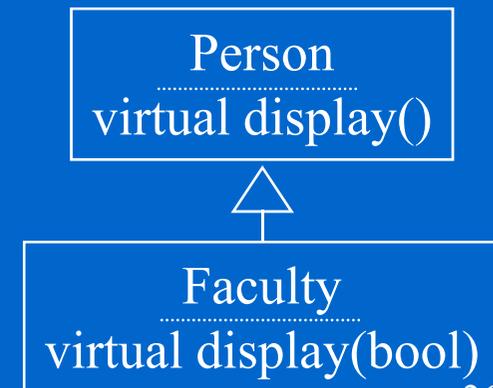
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referrer.function()    referrer->function()

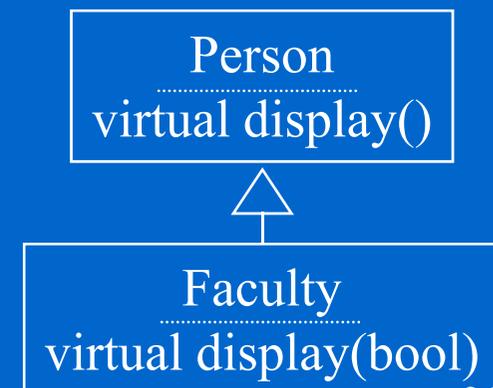


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1. Search in the scope of the static type of the referrer pointer/reference/object to find the specified function in its explicitly defined functions



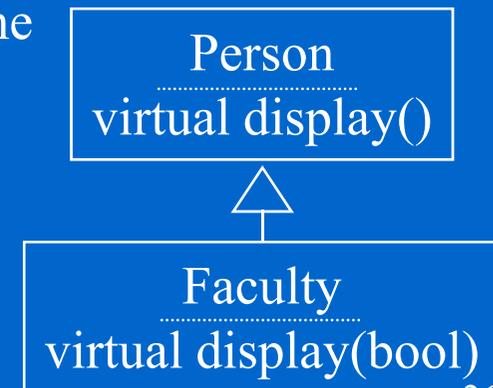
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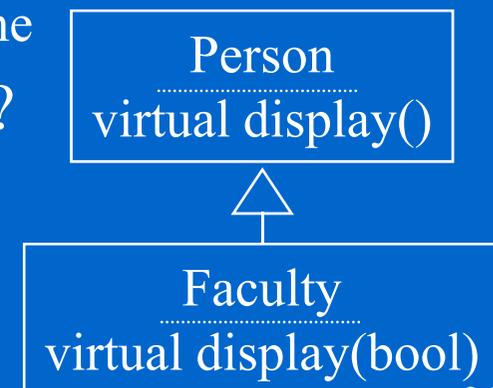
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What functions are explicit in the scope of a class?



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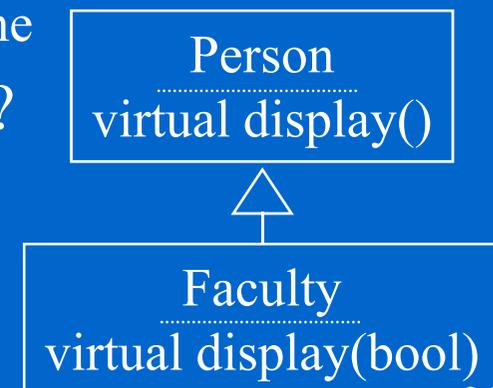
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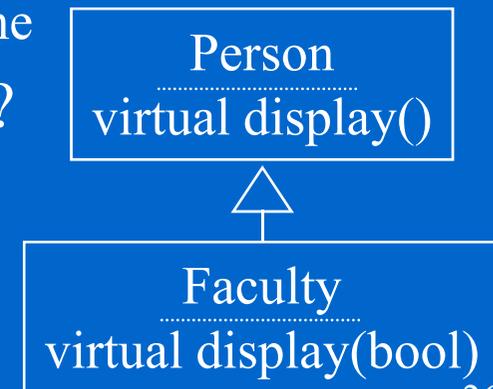
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What functions are explicit in the scope of a class?

1. Defined in the class declaration
2. Search upward the inheritance tree, match all functions not hided previously (by any function having the same name)



# Explicitly Defined Functions

```
class Base {
public:
 void funcA() { cout << "Base::funcA() #1\n"; }
 virtual void funcB() { cout << "Base::funcB() #2\n"; }
 void funcC() { cout << "Base::funcC() #3\n"; }
 virtual void funcD() { cout << "Base::funcD() #4\n"; }
 virtual void funcE() { cout << "Base::funcE() #5\n"; }
 virtual void funcE(int, int) { cout << "Base::funcE(int,int) #6\n"; }
};
```

# Explicitly Defined Functions

```
class Base {
public: Virtual table: 2, 4, 5, 6
 void funcA() { cout << "Base::funcA() #1\n"; }
 virtual void funcB() { cout << "Base::funcB() #2\n"; }
 void funcC() { cout << "Base::funcC() #3\n"; }
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Virtual table: 2, 4, 5, 6

Explicit: 1,2,3,4,5,6

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 virtual void funcE() { cout << "Base::funcE() #5\n"; }
 virtual void funcE(int, int) { cout << "Base::funcE(int,int) #6\n"; }
};
class Derived: public Base {
public:
 void funcC() {
 cout << "Derived::funcC() #7\n";
 }
 void funcD() {
 cout << "Derived::funcD() #8\n";
 }
 virtual void funcE(int) {
 cout << "Derived::funcE(int) #9\n";
 }
};
```

Virtual table: 2, 4, 5, 6

Explicit: 1,2,3,4,5,6

Virtual table: 2, 8, 5, 6, 9

# Explicitly Defined Functions

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class Base {
public:
 void funcA() { cout << "Base::funcA() #1\n"; }
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 virtual void funcE() { cout << "Base::funcE() #5\n"; }
 virtual void funcE(int, int) { cout << "Base::funcE(int,int) #6\n"; }
};
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 cout << "Derived::funcC() #7\n";
 }
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 cout << "Derived::funcE(int) #9\n";
 }
};
 Virtual table: 2, 8, 5, 6, 9
 Explicit: 1,2,7,8,9
 Implicit: 3,4,5,6
```

# Explicitly Defined Functions

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 }
};
class FDerived1: public Derived {
};
```

Virtual table: 2, 4, 5, 6

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Virtual table: 2, 8, 5, 6, 9

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```

Virtual table: 2, 4, 5, 6

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 void funcD() {
 cout << "Derived::funcD() #8\n";
 }
 virtual void funcE(int) {
 cout << "Derived::funcE(int) #9\n";
 }
};

class FDerived1: public Derived {
};

class FDerived2: public Derived {
public:
 void funcE() {
 cout << "FDerived2::funcE() #10\n";
 }
 void funcE(int, int) {
 cout << "FDerived2::funcE(int, int) #11\n";
 }
};
```

Virtual table: 2, 4, 5, 6

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Virtual table: 2, 8, 10, 11, 9

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# Explicitly Defined Functions

```
class Base {
public:
 void funcA() { cout << "Base::funcA() #1\n"; }
 virtual void funcB() { cout << "Base::funcB() #2\n"; }
 void funcC() { cout << "Base::funcC() #3\n"; }
 virtual void funcD() { cout << "Base::funcD() #4\n"; }
 virtual void funcE() { cout << "Base::funcE() #5\n"; }
 virtual void funcE(int, int) { cout << "Base::funcE(int,int) #6\n"; }
};

class Derived: public Base {
public:
 void funcC() {
 cout << "Derived::funcC() #7\n";
 }
 void funcD() {
 cout << "Derived::funcD() #8\n";
 }
 virtual void funcE(int) {
 cout << "Derived::funcE(int) #9\n";
 }
};

class FDerived1: public Derived {
};

class FDerived2: public Derived {
public:
 void funcE() {
 cout << "FDerived2::funcE() #10\n";
 }
 void funcE(int, int) {
 cout << "FDerived2::funcE(int, int) #11\n";
 }
};
```

Virtual table: 2, 4, 5, 6

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- ❖ What are the benefits from polymorphism?  
Superior abstraction of object usage (code reuse),  
**old codes call new codes** (usage prediction)

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database[0] = new Staff(...);
...
show(database);
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  - ★ Doing so ensures the pure OO semantics and have good semantic compatibility if you are using multiple OO languages.
  - ★ You can change to non-virtual (compile-time binding makes the code run faster) when profiling shows that the overhead comes from the virtual function calls

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Virtual function does not always use dynamic binding.  
This is a C++ specific feature.

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  - ★ You can redefine a static function in a derived class. The static function in the base class is *hided* as usual.

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- ★ Note: This syntax makes every destructor of every derived class virtual even though the names do not match. Visual Studio automatically does this.

# Invoking a Virtual function in Ctor/Dtor

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- ❖ Example: Single Dispatch

# Single / Double Dispatch

**x->message(y);**

- ❖ C++ (virtual) function provides only **single dispatch**: the decision of which `message()` to call is based on **the type of x (\*x)**
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- ❖ Example: Single Dispatch

|                                                                             |
|-----------------------------------------------------------------------------|
| Asteroid                                                                    |
| +virtual collideWith(SpaceShip*)<br>+virtual collideWith(ApolloSpacecraft*) |

# Single / Double Dispatch

**x->message(y);**

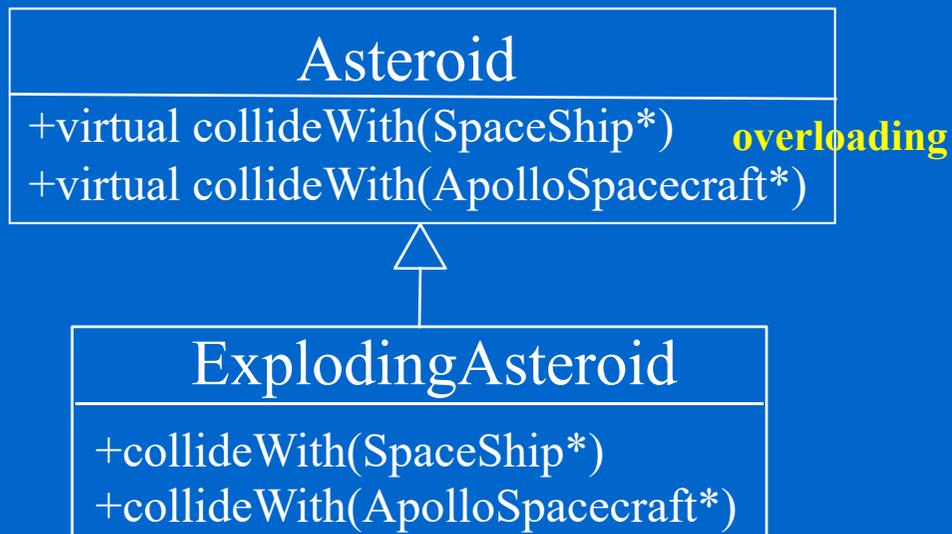
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- ❖ Example: Single Dispatch

| Asteroid                                            |
|-----------------------------------------------------|
| +virtual collideWith(SpaceShip*) <b>overloading</b> |
| +virtual collideWith(ApolloSpacecraft*)             |

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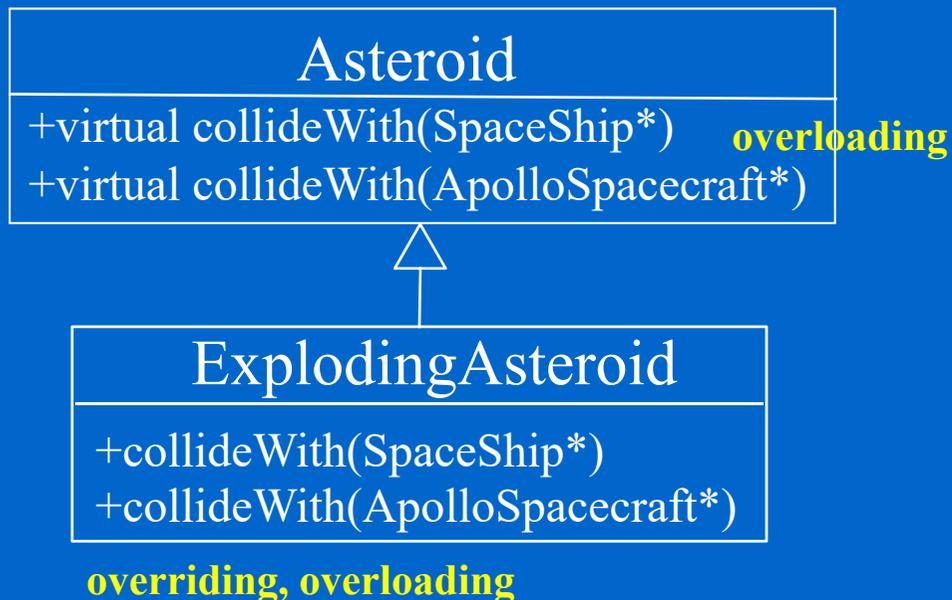
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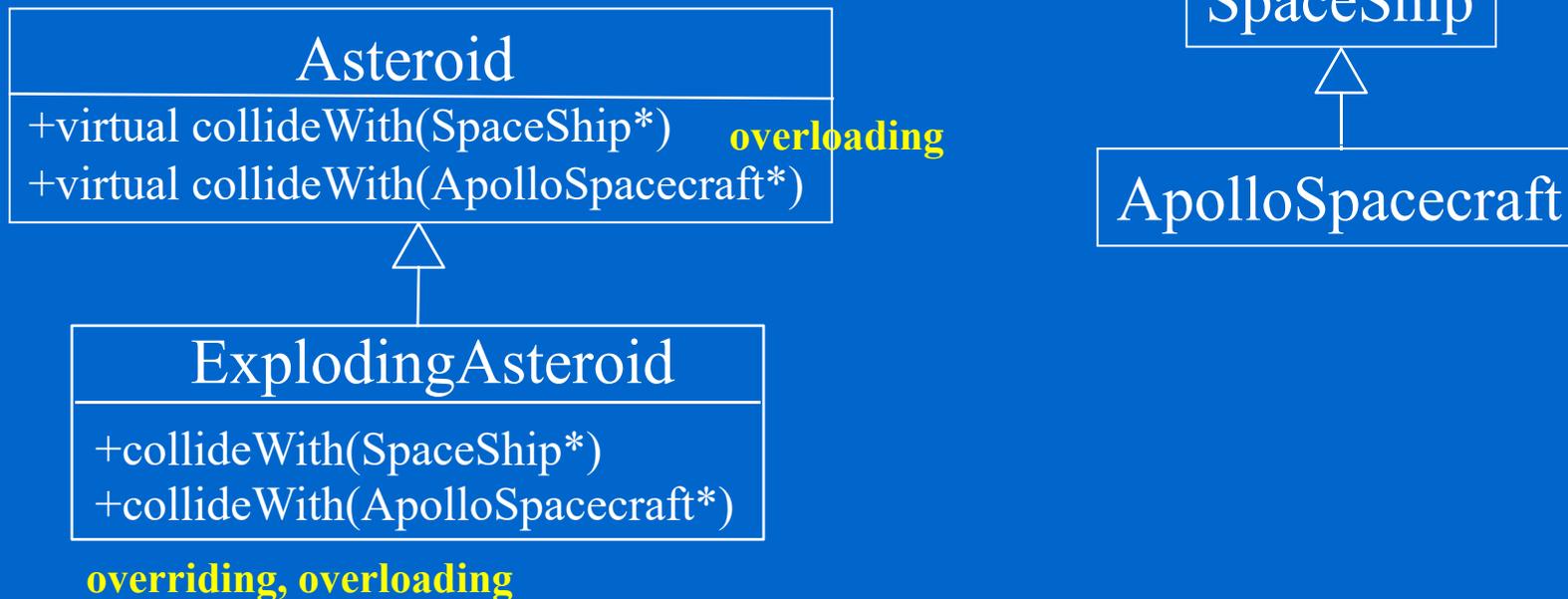
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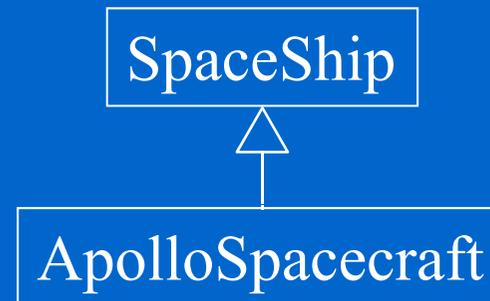
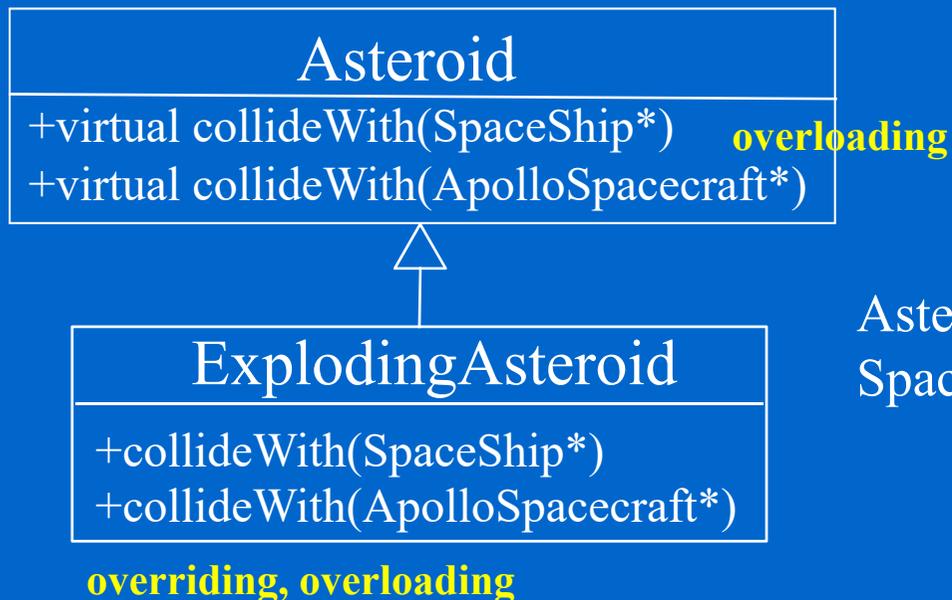
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- ❖ Example: Single Dispatch



Asteroid \*asteroid = new ExplodingAsteroid;  
SpaceShip \*spaceShip = new ApolloSpacecraft;

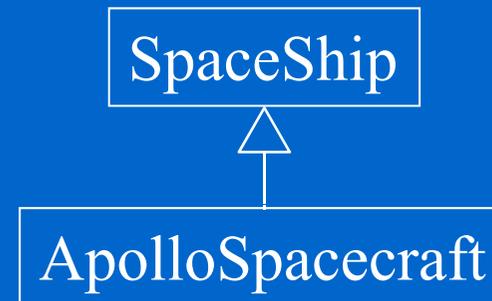
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- ❖ Example: Single Dispatch



**overriding, overloading**



Asteroid \*asteroid = new ExplodingAsteroid;  
SpaceShip \*spaceShip = new ApolloSpacecraft;  
**asteroid->collideWith(spaceShip);**

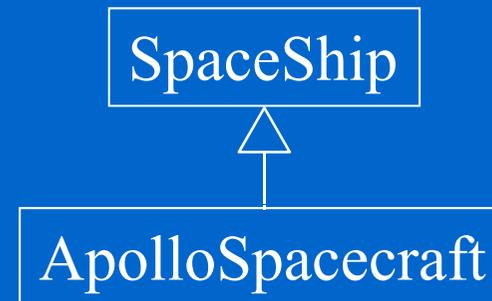
**dynamic dispatch**

**static dispatch**

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- ❖ Example: Single Dispatch



Asteroid \*asteroid = new ExplodingAsteroid;  
SpaceShip \*spaceShip = new ApolloSpacecraft;  
**asteroid->collideWith(spaceShip);**  
delete asteroid; delete spaceShip;

dynamic dispatch

static dispatch

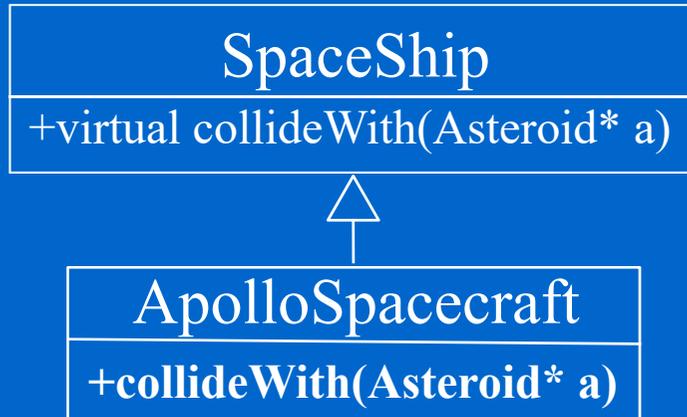
# Double Dispatch (cont'd)

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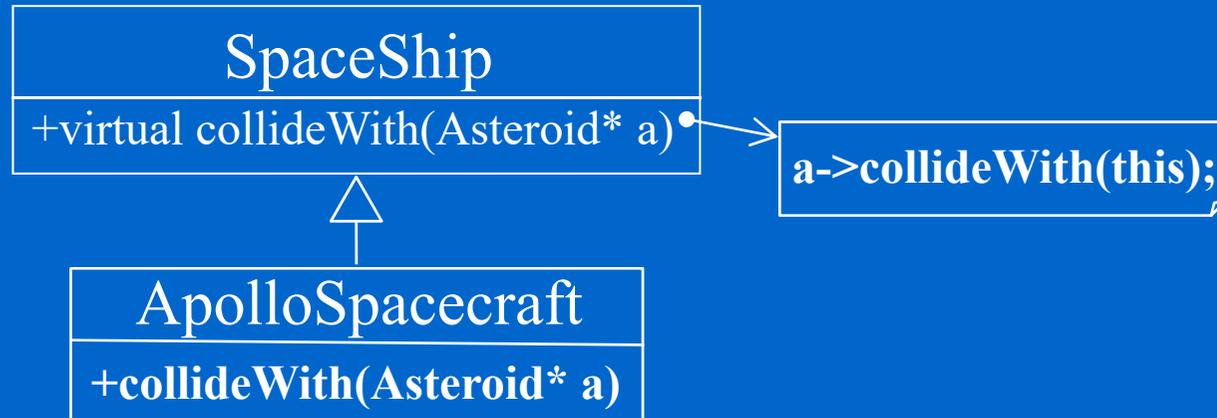
SpaceShip

+virtual collideWith(Asteroid\* a)

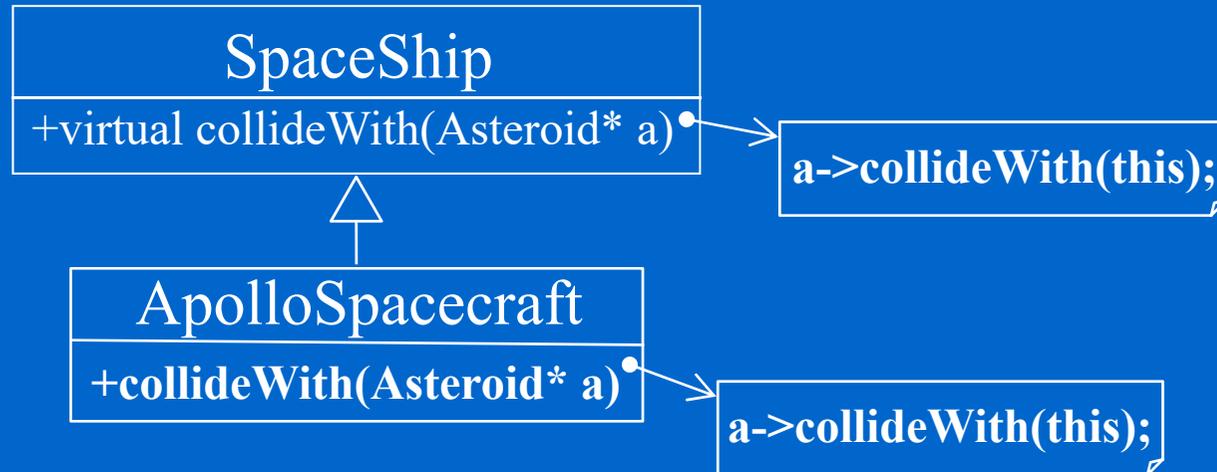
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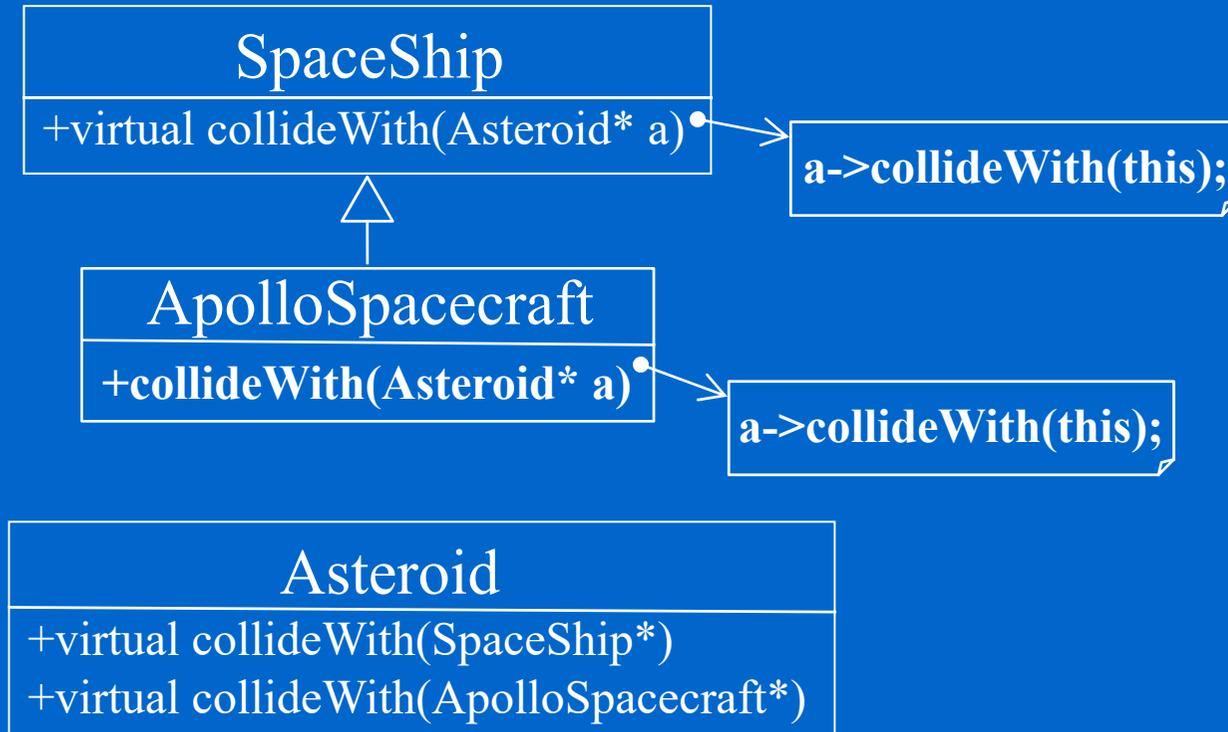
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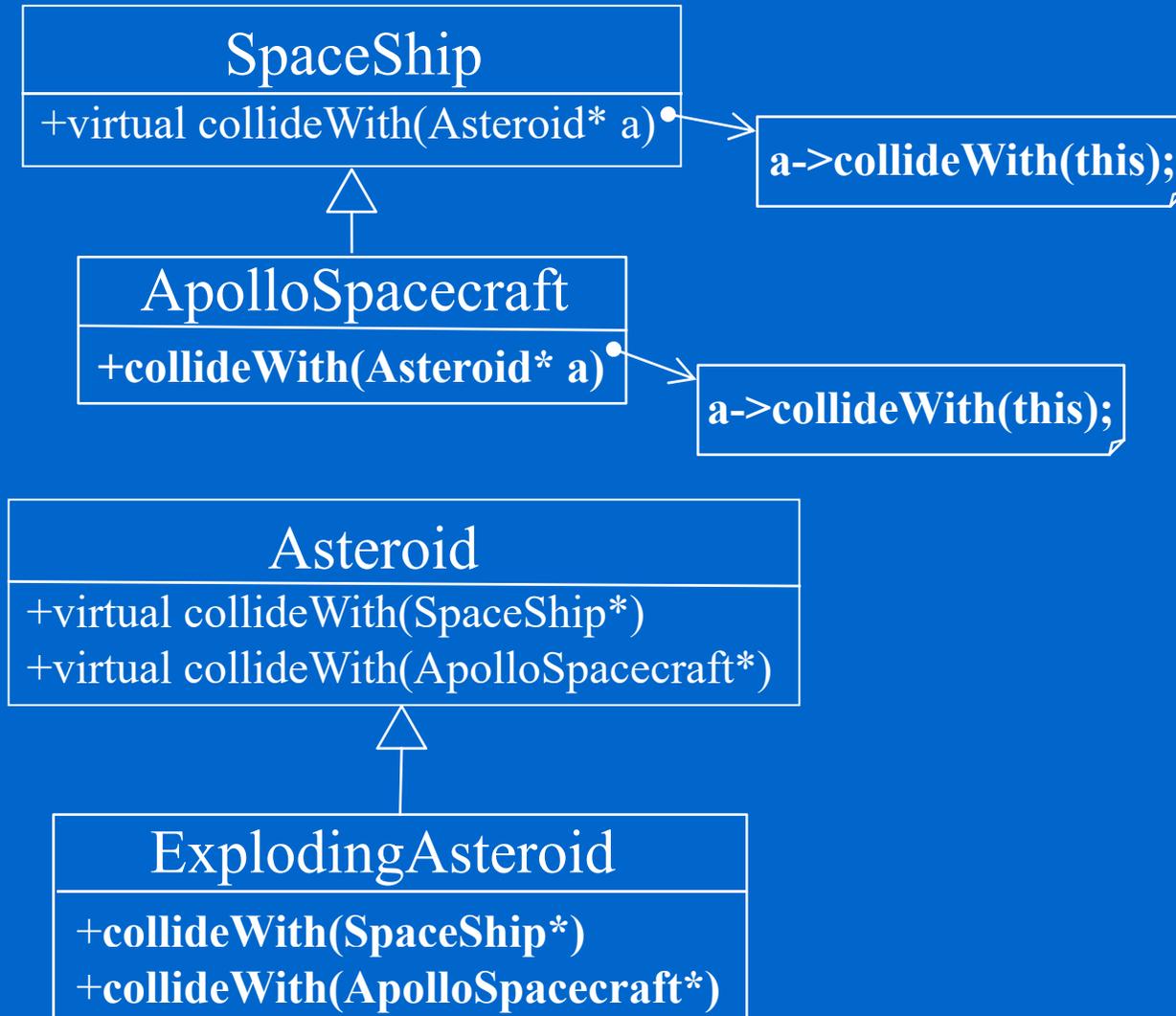
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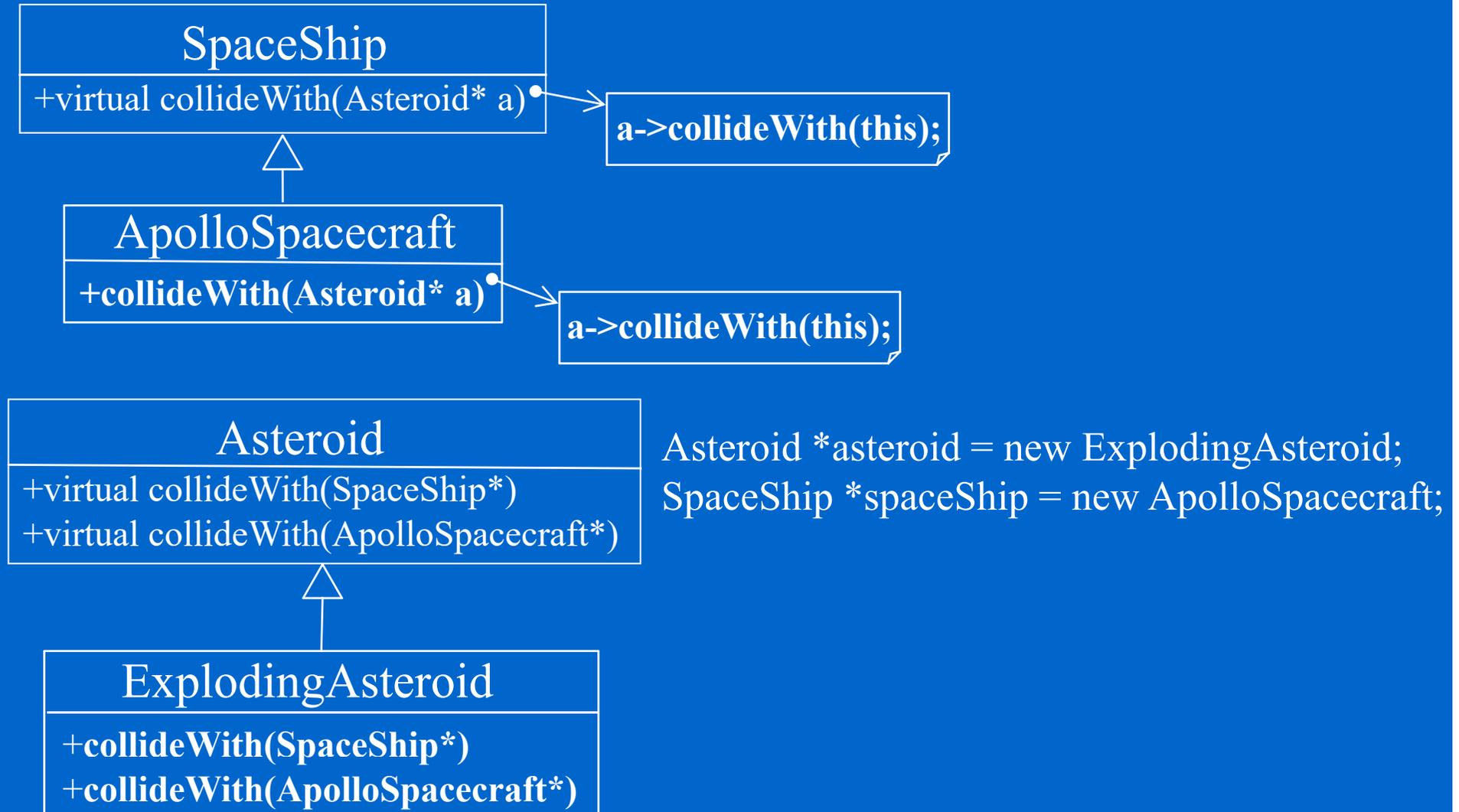
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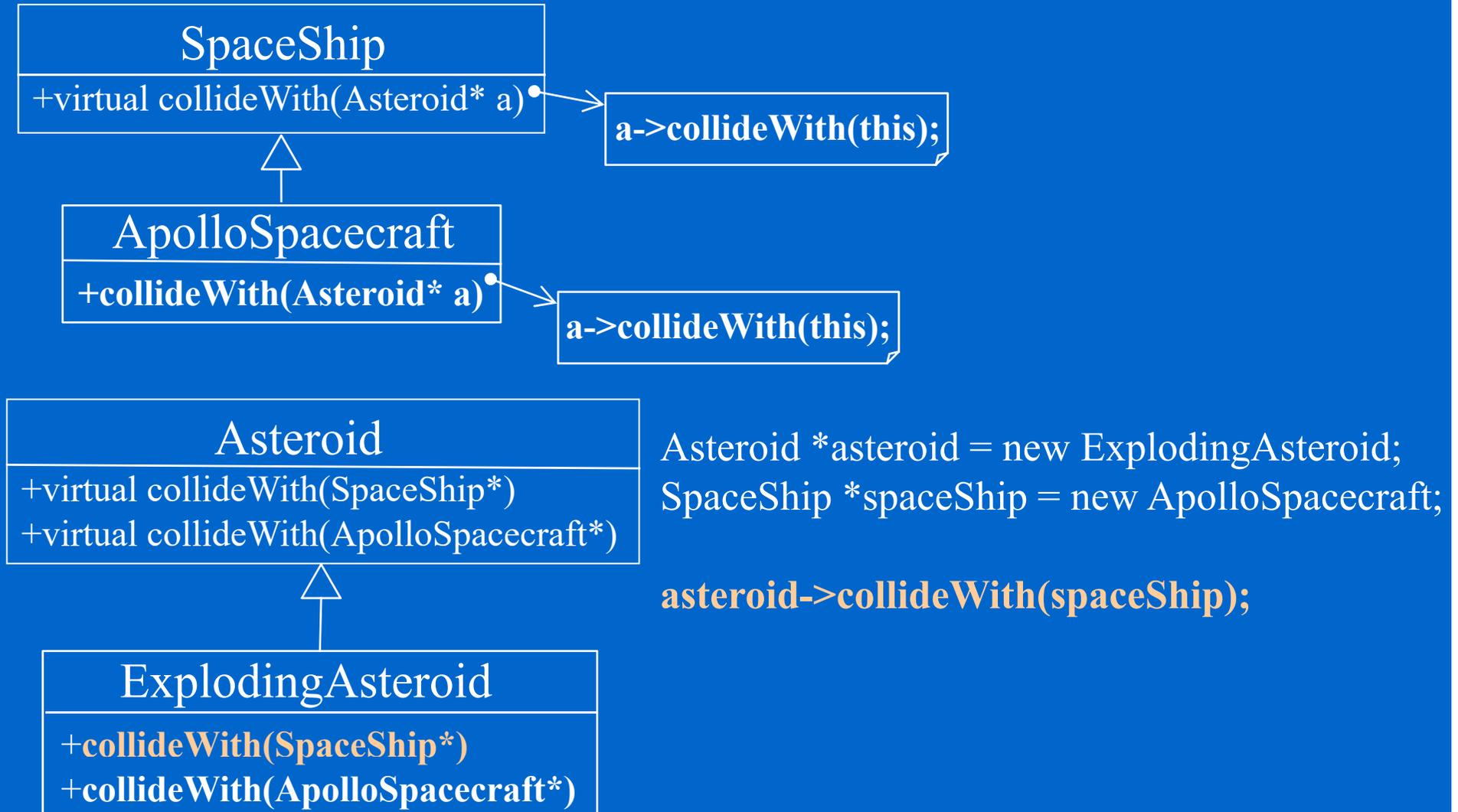
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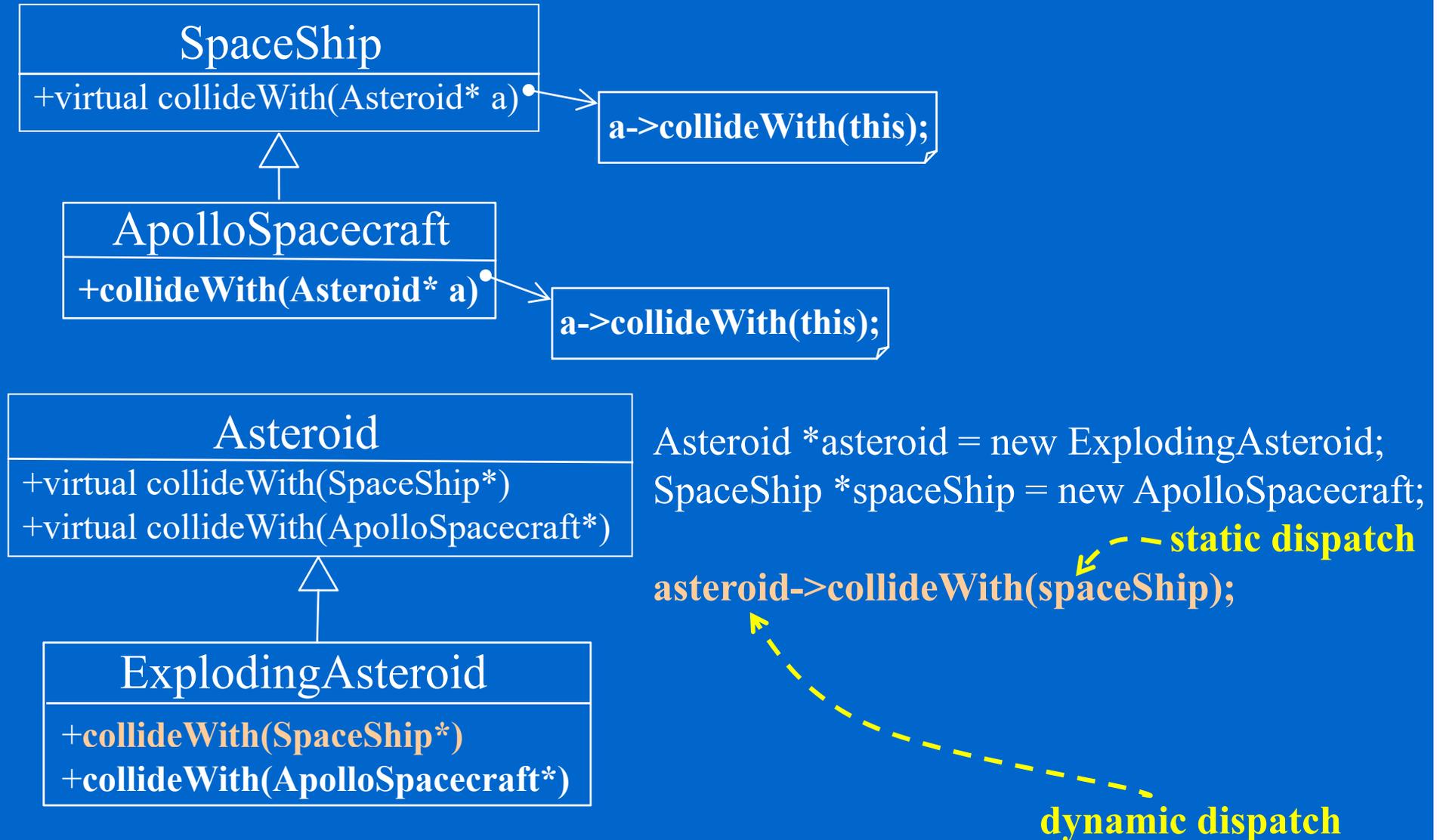
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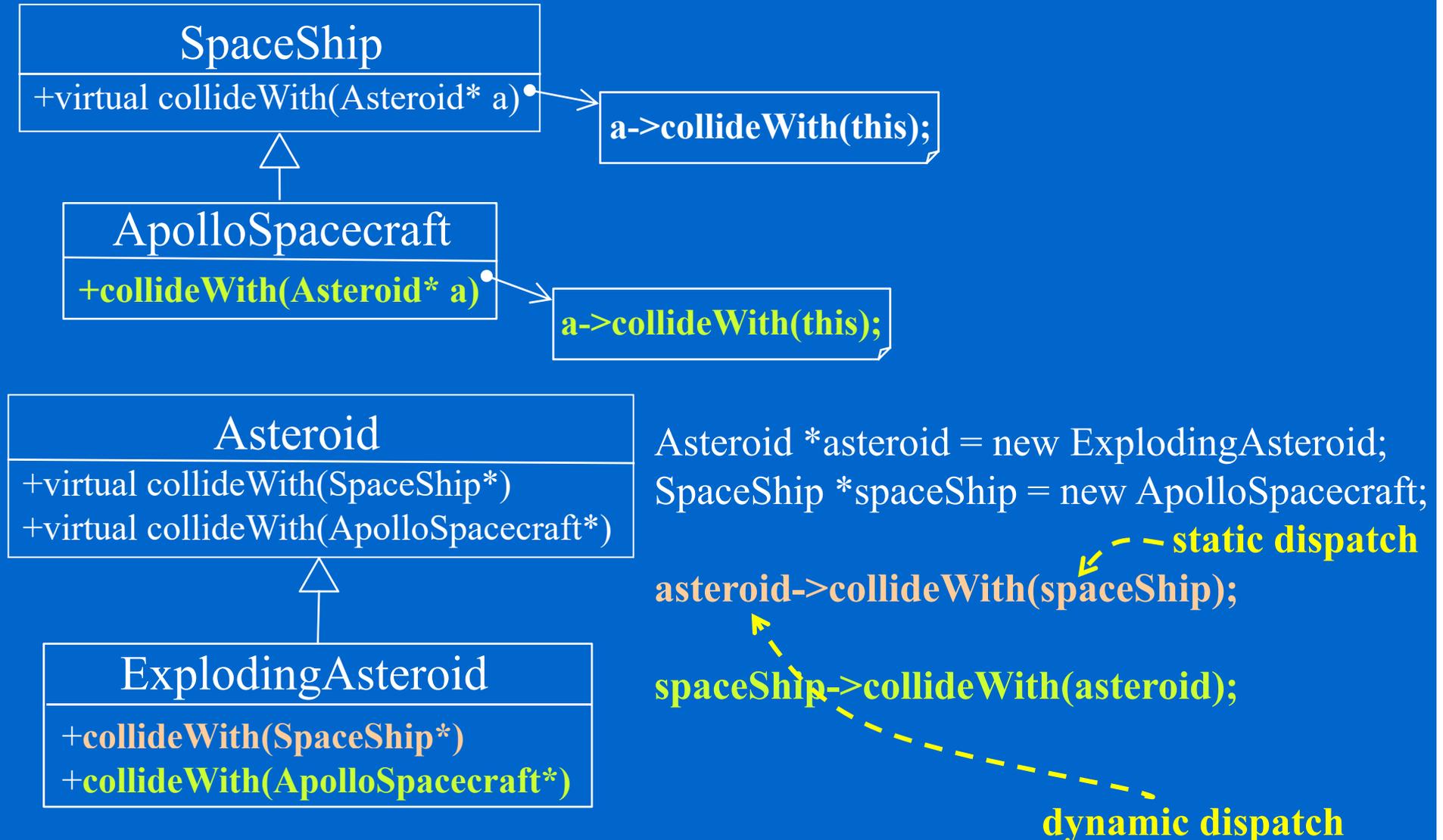
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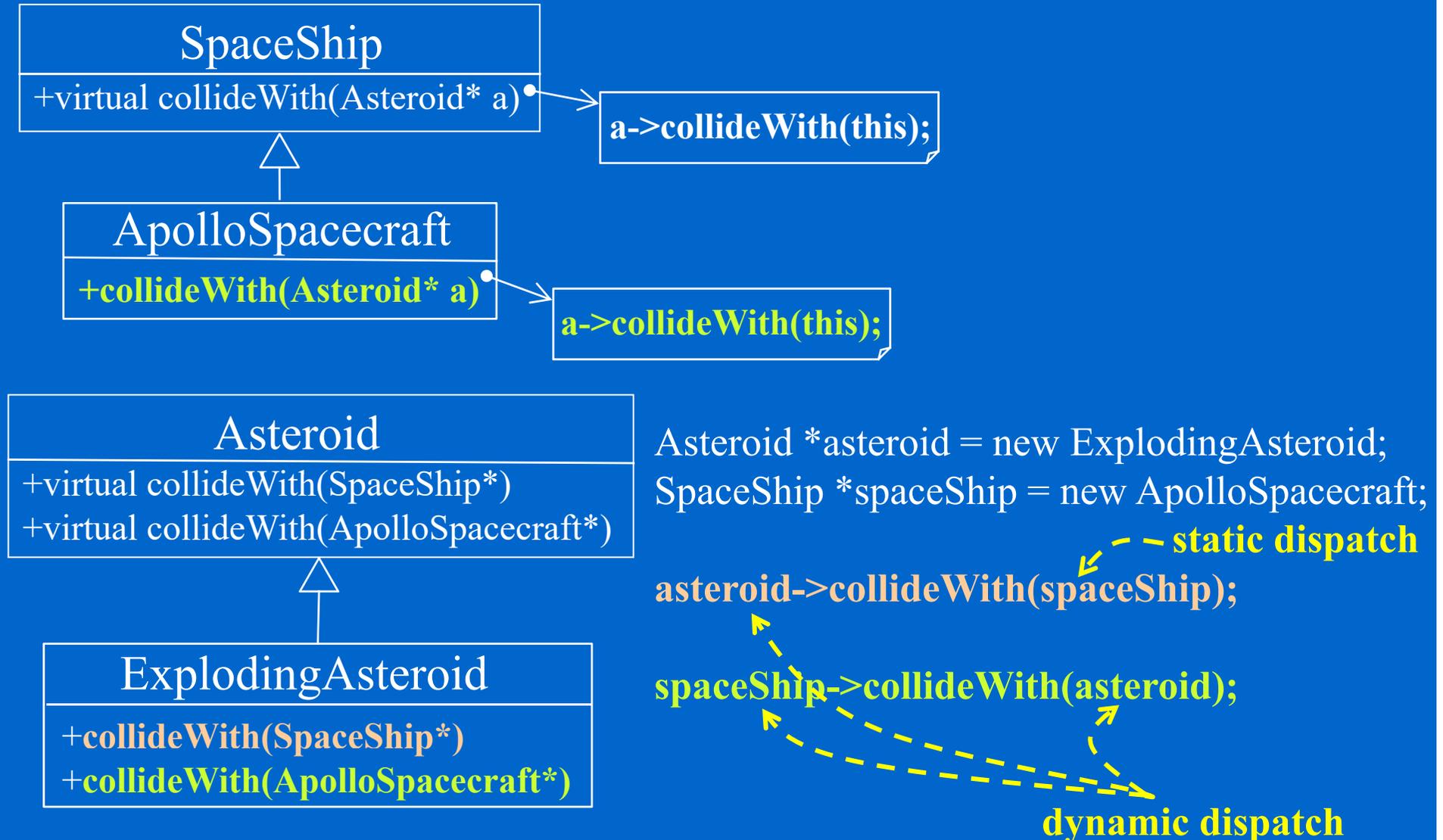
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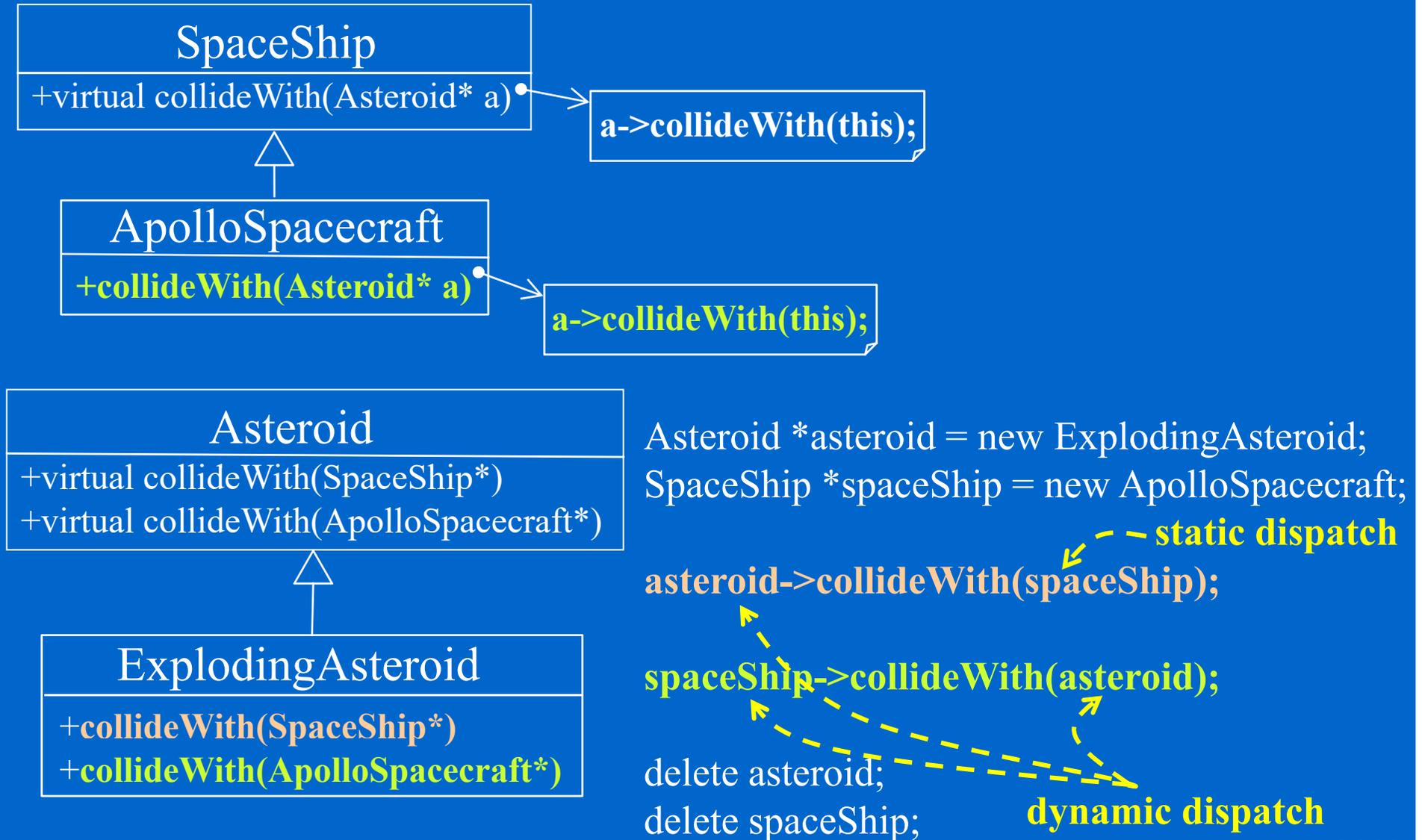
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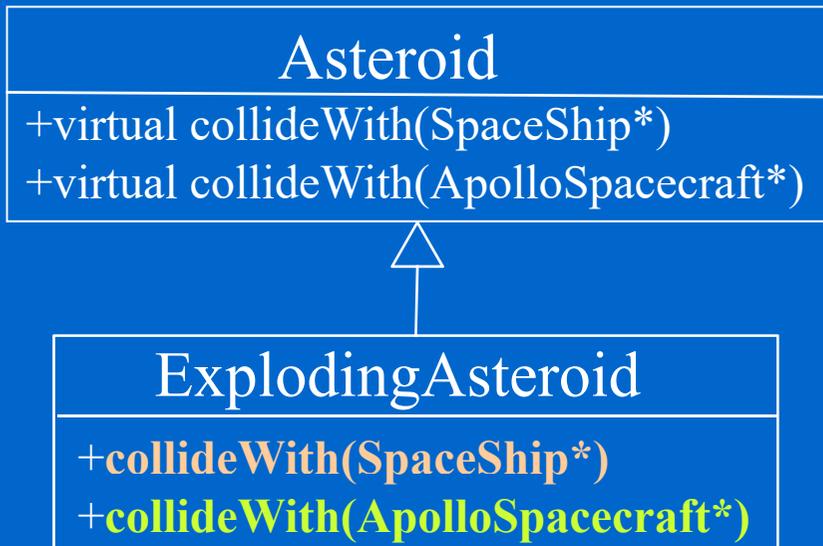
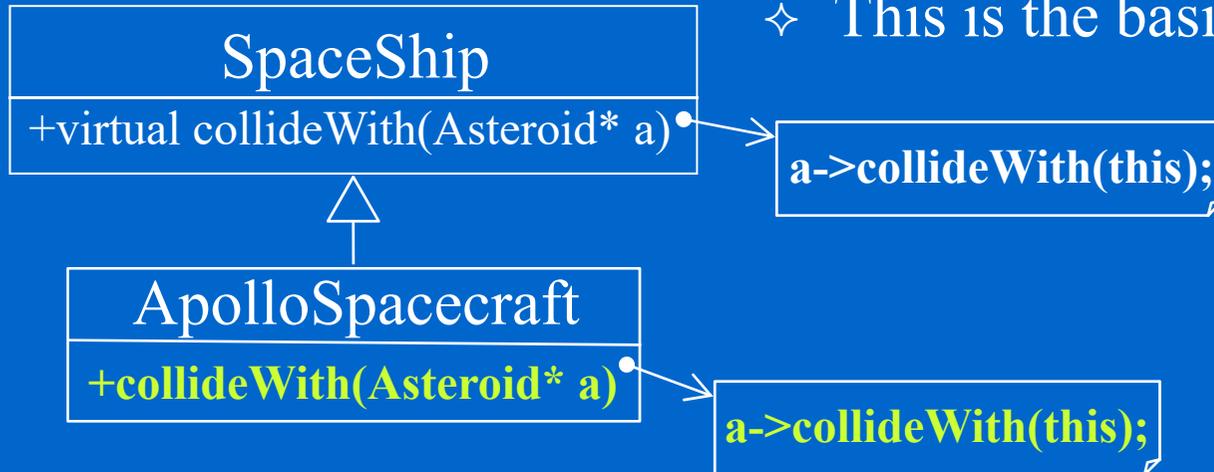


# Double Dispatch (cont'd)



# Double Dispatch (cont'd)

✧ This is the basis of the **Visitor** pattern



Asteroid \*asteroid = new ExplodingAsteroid;  
SpaceShip \*spaceShip = new ApolloSpacecraft;

**asteroid->collideWith(spaceShip);**  
- static dispatch

**spaceShip->collideWith(asteroid);**

delete asteroid;  
delete spaceShip;

**dynamic dispatch**

# Visitor Pattern

- ✧ A way of separating an **algorithm** from an **object structure on which it operates** such that it is possible to **add new operations to existing object structures** without modifying those structures and enforcing the OCP.

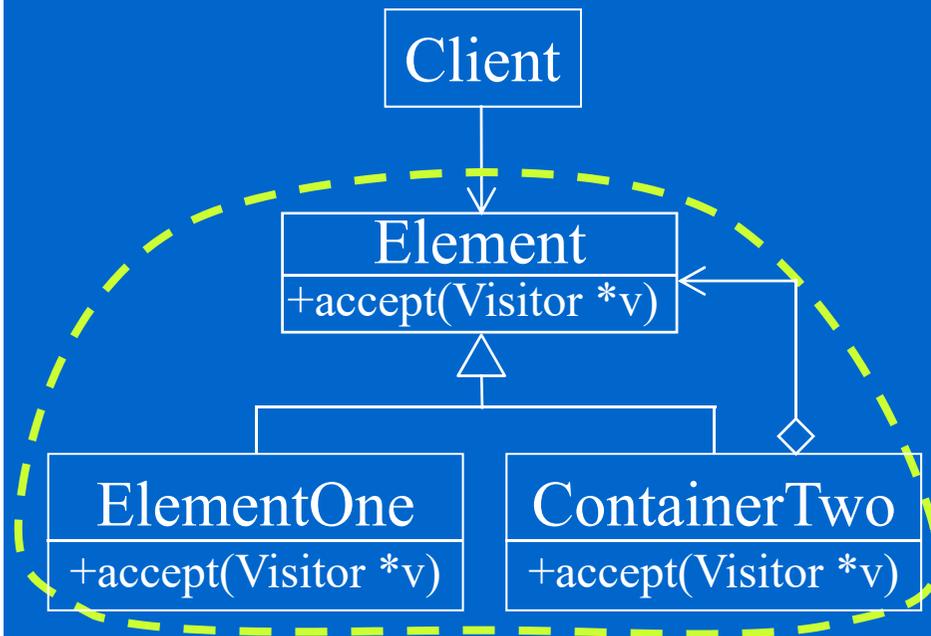
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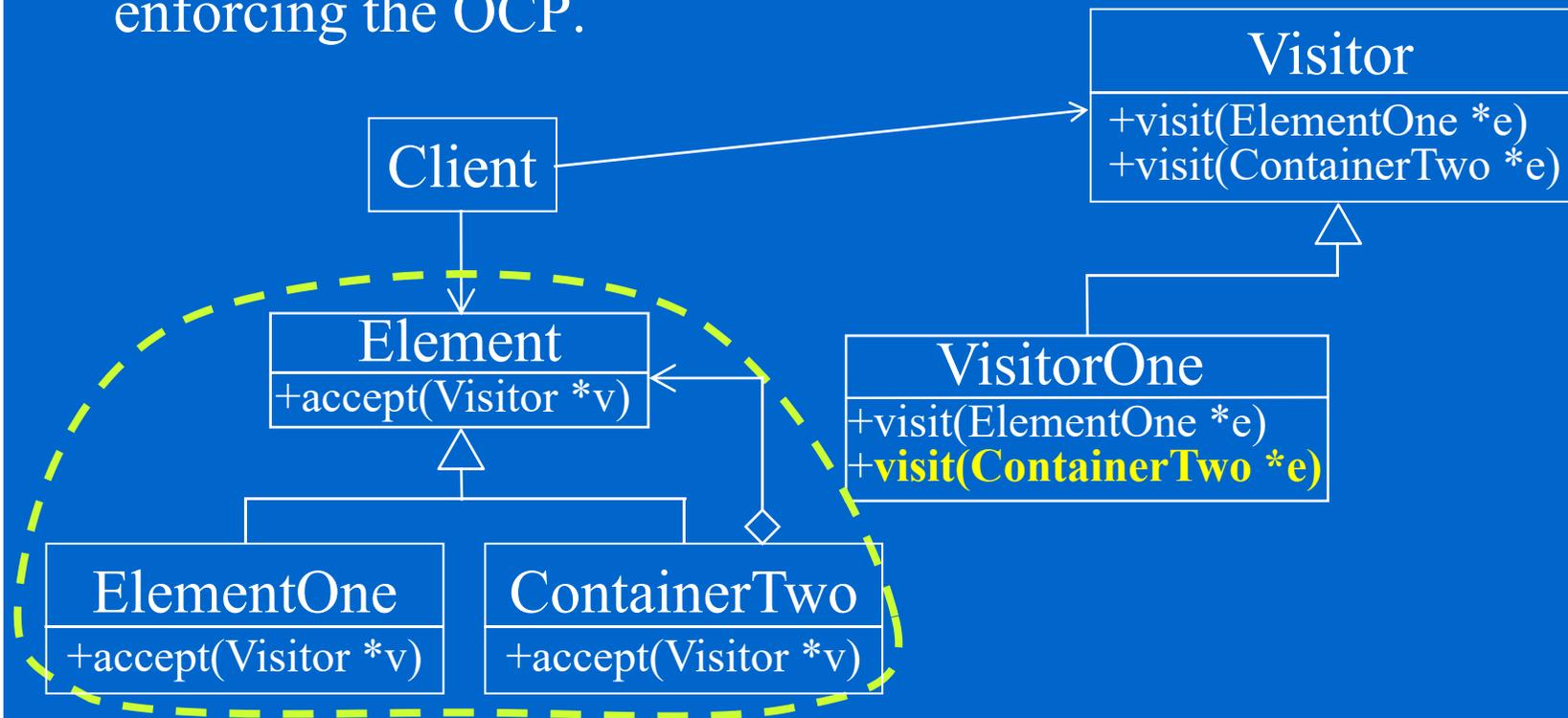
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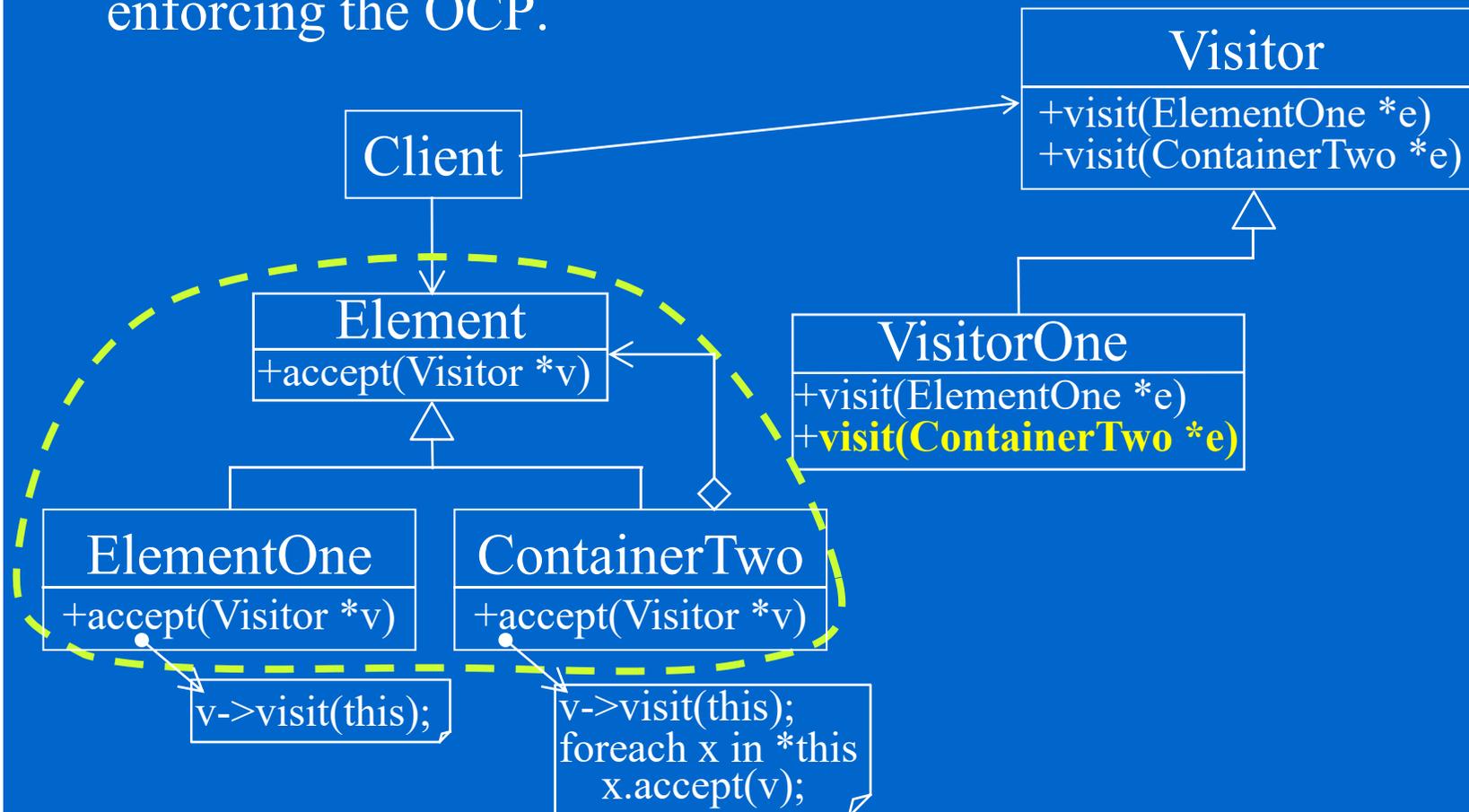
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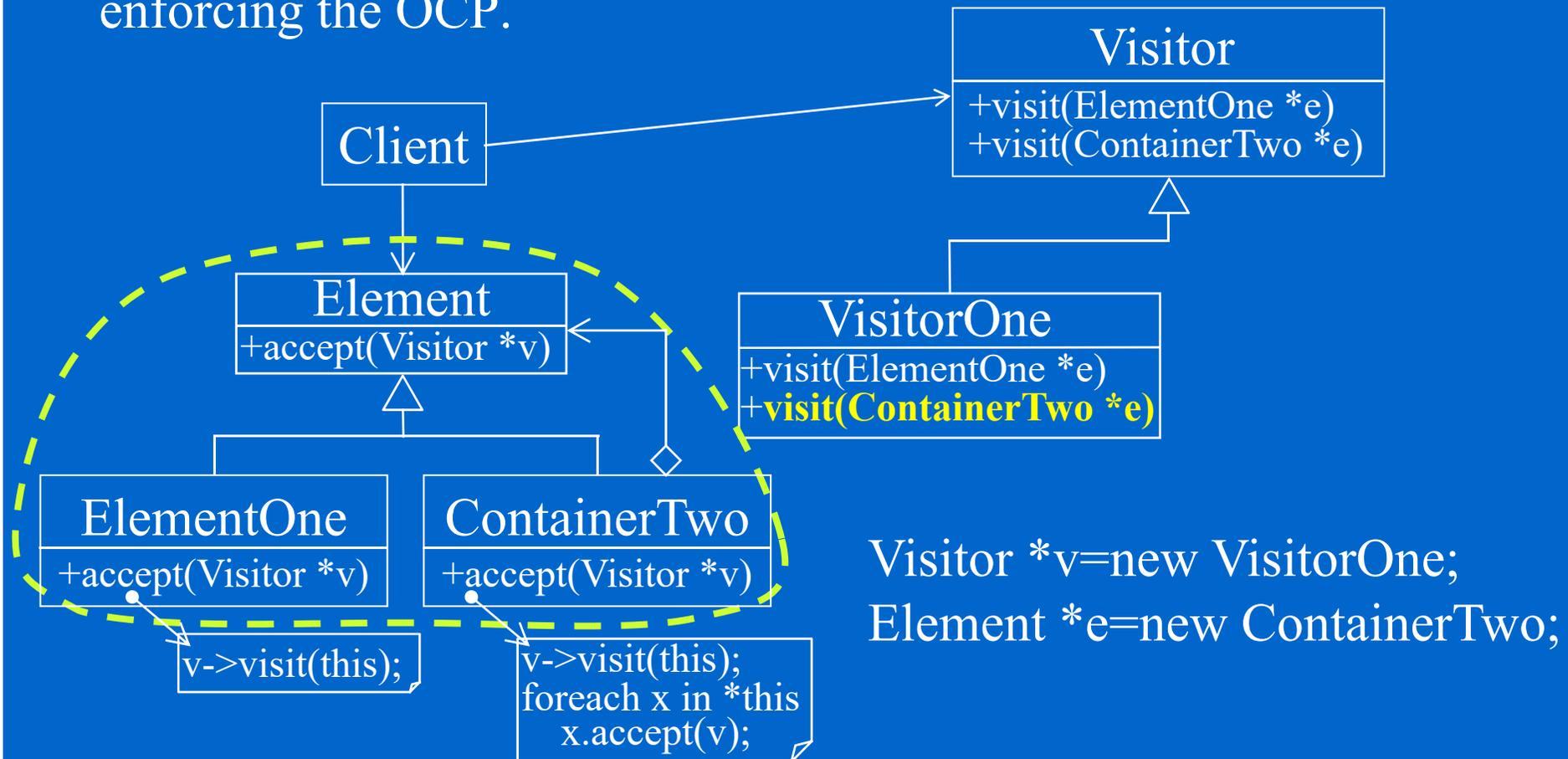
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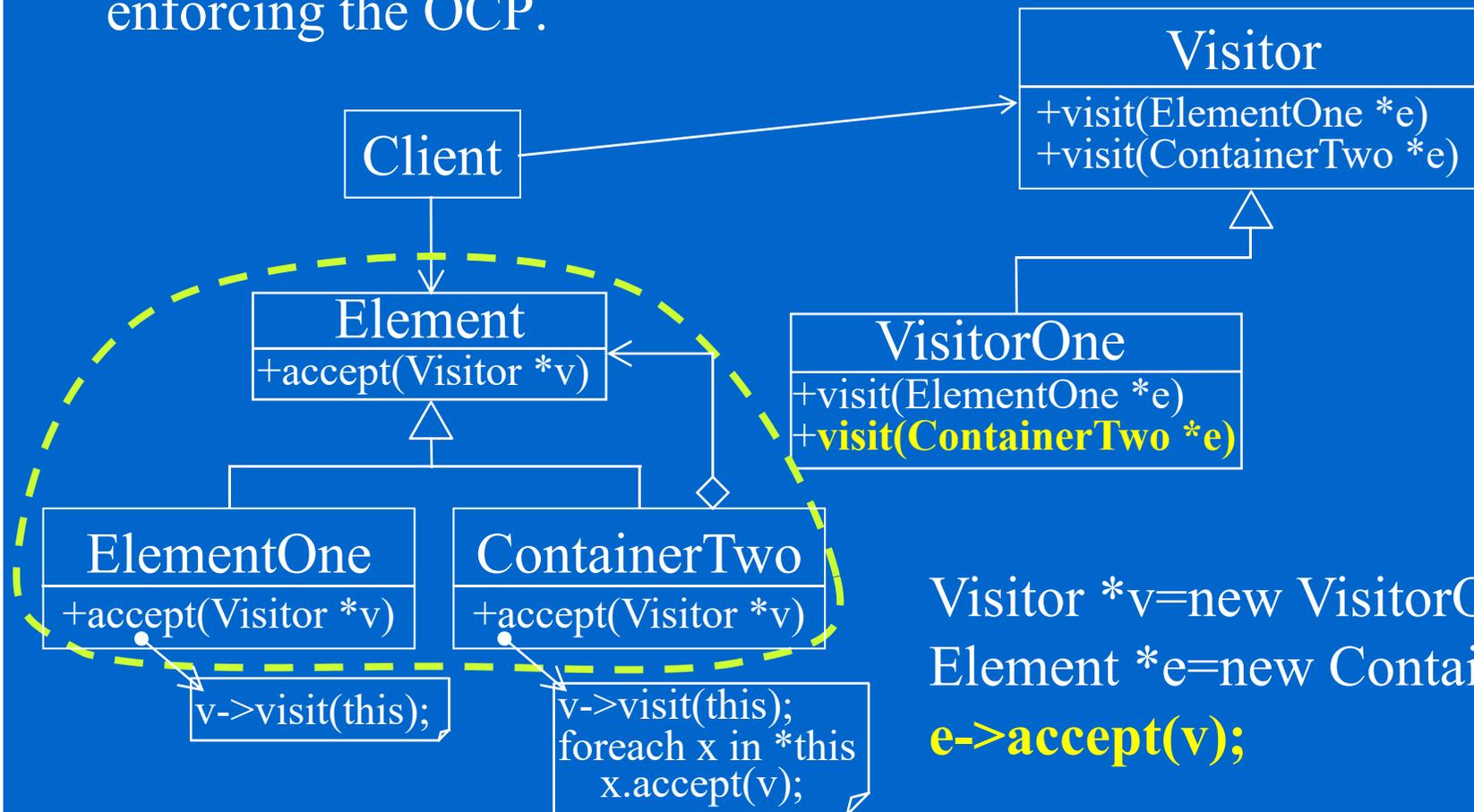
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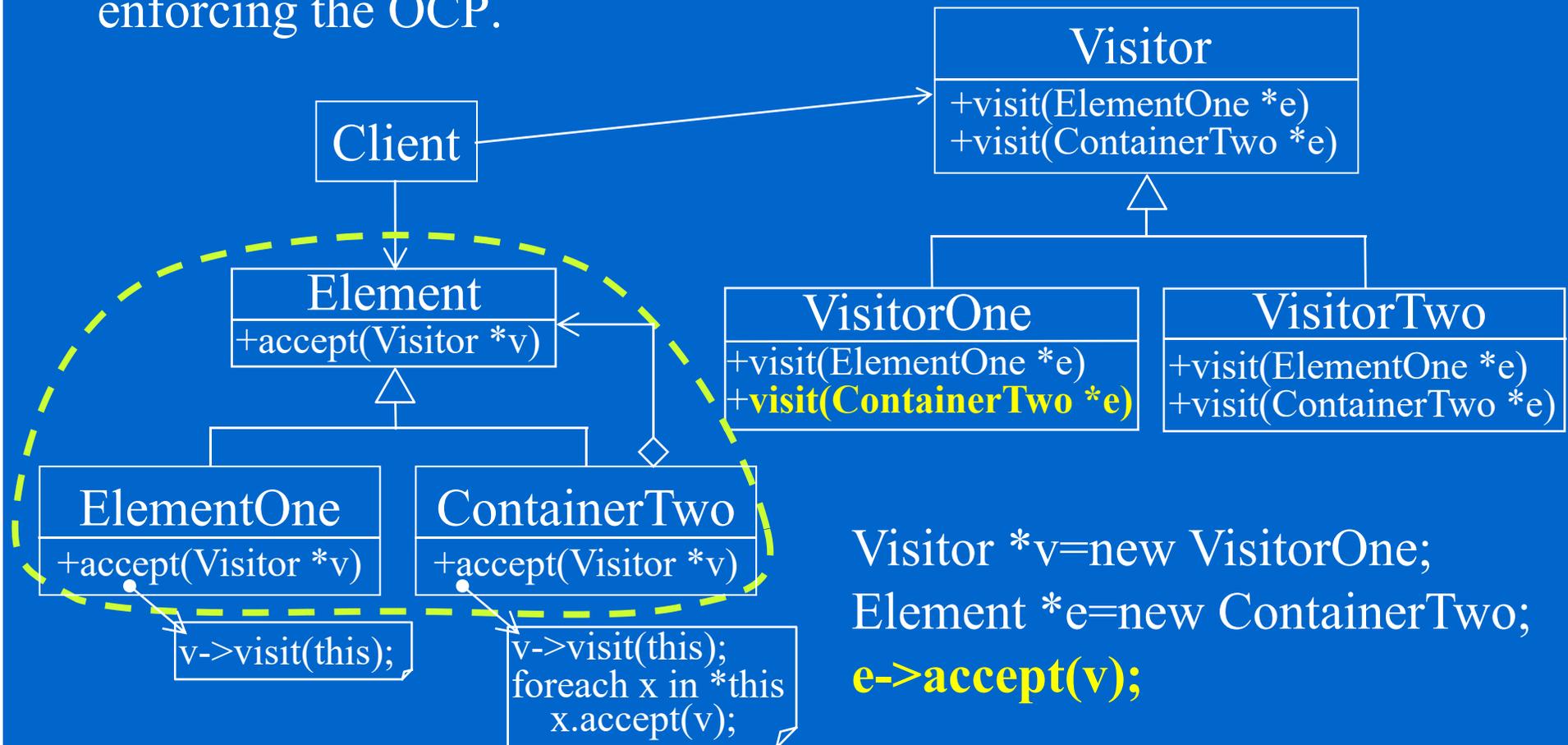
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