i219 Software Design Methodology
5. Object-oriented programming language 2

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Outline of lecture

- Method dispatch
- Inner interface/class
- Enum type

Method dispatch (1)

For a while, let us only consider methods that have no arguments. Under the condition, let us consider the class diagram:

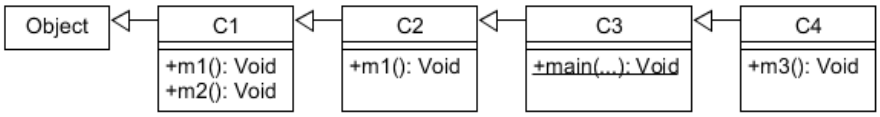
where C_0 is Object

When a message m( ) is sent to an object a_n of C_n, the search for the method invoked basically starts with C_n; if there exists i ($0 \leqq i \leqq n$) such that C_i has the method m( ), and each C_k ($i+1 \leqq k \leqq n$) does not have such a method, then the method in C_i is invoked.

Note that executing o.m( ) where o is a variable of C_i ($i \neq 1$) but refers to an object of C_n, the search starts with C_n.

Note that compiling o.m( ) fails if o is a variable of C_i such that $C_0, \ldots, C_i$ do not have m( ); type casting may make the compilation successful.

Method dispatch (2)



(new C4()).m1();	m1() in C2 is invoked.
(new C4()).m2();	m2() in C1 is invoked.
(new C4()).m3();	m3() in C4 is invoked.
C1 o = new C4();	
o.m1();	m1() in C2 is invoked.
o.m2();	m2() in C1 is invoked.
o.m3();	A compiler error occurs.

Method dispatch (3)

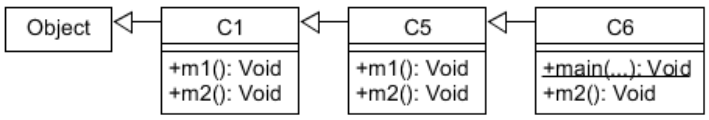
There are two pseudo-variables that refer to the currently active object: this and super.

Let both this and super refer to an object of C_n.

If a message m() is sent to this, the search for the method invoked starts with C_n as the message is sent to an object of C_n.

If a message m() is sent to super, the search for the method invoked starts with the super class of the class in which super.m() appears.

Method dispatch (4)



(new C6()).m1(); m1() in C5 is invoked.

m1() in C5 is as follows:

```
public void m1() {
    System.out.println("m1() in C5 was invoked.");
    this.m2();          m2() in C6 is invoked.
    super.m2();         m2() in C1 is invoked.
}
```

Method dispatch (5)

A sequence $\tau_1, \ldots, \tau_m$ of types is compatible with a parameter $t_1\ p_1, \ldots, t_n\ p_n$ if $m = n$ and for each i $(1 \leqq i \leqq n)$ τ_i is the same as t_i or a subtype of t_i.

E.g., C4, C4 is compatible with C3 x, C4 y.

$t_1\ p_1, \ldots, t_n\ p_n \leqq t'_1\ p'_1, \ldots, t'_{m'}\ p'_{m'}$ if $m' = n$ and for each i $(1 \leqq i \leqq n)$ t_i is the same as t'_i or a subtype of t'_i.

E.g., x:C3, y:C4 $\leqq$ x:C2, y:C3.

Note that if $\tau_1, \ldots, \tau_m$ is compatible with $t_1\ p_1, \ldots, t_n\ p_n$ and $t_1\ p_1, \ldots, t_n\ p_n \leqq t'_1\ p'_1, \ldots, t'_{m'}\ p'_{m'}$ then $\tau_1, \ldots, \tau_m$ is compatible with $t'_1\ p'_1, \ldots, t'_{m'}\ p'_{m'}$

E.g., C4, C4 is also compatible with x:C2, y:C3.

Method dispatch (6)

Let $\boldsymbol{P}$ be a set of parameters with which $\tau_1, \ldots, \tau_m$ is compatible.

$P \in \boldsymbol{P}$ is called the minimum (or least) element of $\boldsymbol{P}$ if $P \leqq P'$ for all $P' \in \boldsymbol{P}$.

E.g., {(C3 x, C4 y), (C2 x, C3 y), (C3 x, C2 y), (C2 x, C2 y), (C1 x, C2 y)} is a set of parameters with which C4, C4 is compatible. C3 x, C4 y is the minimum element of the set.

E.g., {(C2 x, C2 y), (C1 x, C2 y)} is a set of parameters with which C2, C2 is compatible. C2 x, C2 y is the minimum element of the set.

E.g., {(C2 x, C3 y), (C3 x, C2 y), (C2 x, C2 y), (C1 x, C2 y)} is a set of parameters with which C3, C3 is compatible. The set does not have the minimum element .

Method dispatch (6)

Let us consider $obj.\mathrm{m}(v_1, \ldots, v_m)$ that appears in C_k.

For each v_j, let t_j be its type that can be known at compile time and C_{obj} be the class of obj that can be known at compile time.

E.g., if v_j (or obj) is new C2(), t_j (or C_{obj}) is C2, if v_j (or obj) is x that is a variable declared as C1 x, then t_j (or C_{obj}) is C1 even though an object of C2 is stored in x, if v_j (or obj) is the pseudo-variable this, t_j (or C_{obj}) is C_k, and if v_j is 3.14, t_j is double.
If obj is the pseudo-variable super, C_{obj} is C_{k-1} (the super class of C_k). Note that super cannot be used as an actual parameter of a method, such as v_j.

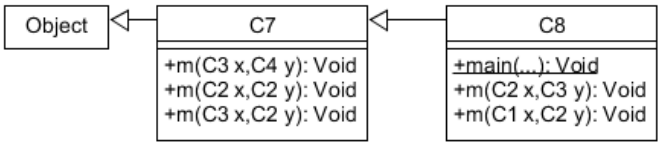
Method dispatch (6)

Let $\boldsymbol{M}$ be the set of methods in $\mathrm{C}_0, \ldots, \mathrm{C}_{obj}$ such that their names are the same as m, and $\boldsymbol{P}$ be $\{P \mid \mathrm{m}(P) \in \boldsymbol{M}, t_1, \ldots, t_m$ is compatible with $P\}$.

If $\boldsymbol{P}$ has the minimum element $P_{\min}$, then the method signature $\mathrm{m}(P_{\min})$ is bound to the message passing statement $obj.\mathrm{m}(v_1, \ldots, v_m)$ at compile time. Otherwise, an error occurs.

The method dispatch for $obj.\mathrm{m}(v_1, \ldots, v_m)$ at runtime is done in the same way as that for $obj.\mathrm{m}()$ where m has no parameters. The method signature of the method invoked for the latter case is $\mathrm{m}()$, while that for the former is $\mathrm{m}(P_{\min})$.

Method dispatch (7)

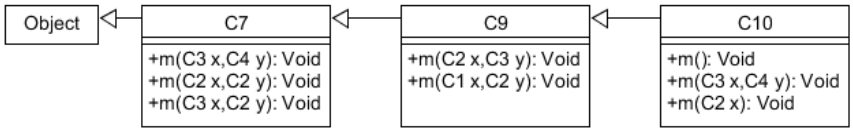



```
(new C8()).m(new C4(),new C4());
```
m(C3 x,C4 y) in C7 is invoked.

```
C2 x = new C4();
C2 y = new C4();
(new C8()).m(x,y);
```
m(C2 x,C2 y) in C7 is invoked.

```
(new C8()).m(new C3(),new C3());
```
A compiler error occurs.

Method dispatch (8)

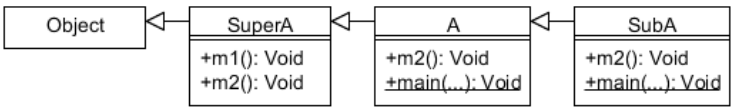



```
(new C10()).m();
```
m() in C10 is invoked.

m1() in C10 is as follows:

```
public void m() {
   System.out.println("m() in C10 was invoked.");
   this.m(new C4(),new C4());
   super.m(new C4(),new C4());
   this.m(new C3());
   // super.m(new C3()); // if uncommented, javac complains.
}
```
m(C3 x,C4 y) in C10 is invoked.
m(C3 x,C4 y) in C7 is invoked.
m(C2 x) in C10 is invoked.

Method dispatch (9)



if this refers to an object of SubA, A & SuperA,
then m2() in SubA, A & SuperA are invoked, respectively

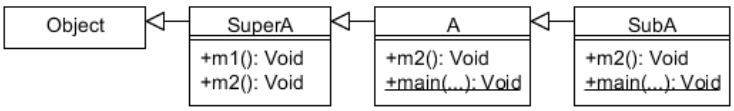
```
public void m1() {  System.out.print("m1() in SuperA;");  this.m2();  }
public void m2() {  System.out.println("m2() in SuperA;");  }

public void m2() {  System.out.print("m2() in A;");  super.m2();   }
```

m2() in SuperA is invoked

```
public void m2() {  System.out.print("m2() in SubA;");  super.m2();  }
```

m2() in A is invoked

Method dispatch (10)



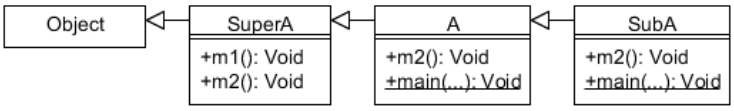

```
public void m1() {  System.out.print("m1() in SuperA;");  this.m2();  }
public void m2() {  System.out.println("m2() in SuperA;");  }
public void m2() {  System.out.print("m2() in A;");  super.m2();   }
public void m2() {  System.out.print("m2() in SubA;");  super.m2();  }
```

main(…) in A is as follows:

```
public static void main(String[] args) { (new A()).m1(); }
```

m1() in SuperA;m2() in A;m2() in SuperA;

Method dispatch (11)



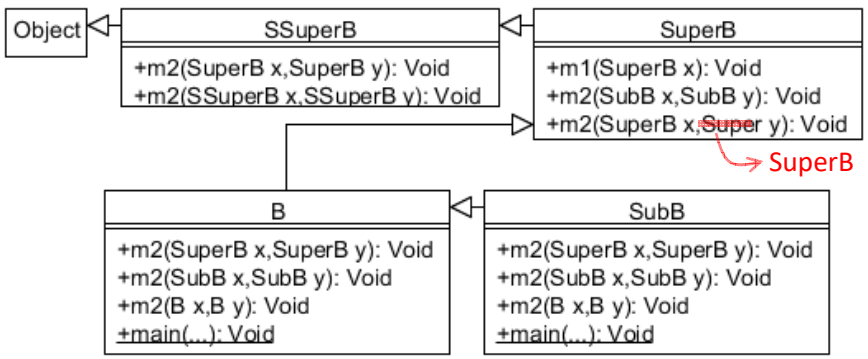

```
public void m1() {  System.out.print("m1() in SuperA;");  this.m2();  }
public void m2() {  System.out.println("m2() in SuperA;");  }
public void m2() {  System.out.print("m2() in A;");  super.m2();   }
public void m2() {  System.out.print("m2() in SubA;");  super.m2();  }
```

main(…) in SubA is as follows:

```
public static void main(String[] args) { (new SubA()).m1(); }
```

m1() in SuperA;m2() in SubA;m2() in A;m2() in SuperA;

Method dispatch (12)



Method dispatch (13)

In SSuperB:

```
m2(SuperB x,SuperB y)
{ …println("m2(SuperB x,SuperB y) in SSuperB;"); }
m2(SSuperB x,SSuperB y)
{ …println("m2(SSuperB x,SSuperB y) in SSuperB;"); }
```

In SuperB:

```
m1(SuperB x) { …print("m1(SuperB x) in SuperB;"); AMsgPassing }
m2(SubB x,SubB y) { …println("m2(SubB x,SubB y) in SuperB;"); }
m2(SuperB x,SuperB y)
{ …println("m2(SuperB x,SuperB y) in SuperB;"); }
```


Method dispatch (14)

In B:

```
m2(SuperB x,SuperB y) { …print("m2(SuperB x,SuperB y) in B;");
   super.m2(new B(),new B());  }
m2(SubB x,SubB y) { …print("m2(SubB x,SubB y) in B;");
   super.m2(new B(),new B());  }
m2(B x,B y) { …print("m2(B x,B y) in B;");  super.m2(new B(),new B());  }
main(String[] args) { (new B()).m1(new B()); }
```

In SubB:

```
m2(SuperB x,SuperB y) { …print("m2(SuperB x,SuperB y) in SubB;");
   super.m2(x,y);  }
m2(SubB x,SubB y) { …print("m2(SubB x,SubB y) in SubB;");
   super.m2(x,y);  }
m2(B x,B y) { …print("m2(B x,B y) in SubB;");
   super.m2(x,y);  }
main(String[] args) { (new SubB()).m1(new B()); }
```

Method dispatch (15)

1. *AMsgPassing* is (new SubB()).m2(new B(),new B());

% java B
m1(SuperB x) in SuperB;m2(B x,B y) in SubB;m2(B x,B y) in B;m2(SuperB x,SuperB y) in SuperB;

% java SubB
m1(SuperB x) in SuperB;m2(B x,B y) in SubB;m2(B x,B y) in B;m2(SuperB x,SuperB y) in SuperB;

2. *AMsgPassing* is this.m2(new B(),new B());

% java B
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in SubB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

Method dispatch (16)

3. *AMsgPassing* is this.m2(new SubB(),new SubB());

% java B
m1(SuperB x) in SuperB;m2(SubB x,SubB y) in B;m2(SuperB x,SuperB y) in SuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SubB x,SubB y) in SubB;m2(SubB x,SubB y) in B;m2(SuperB x,SuperB y) in SuperB;

4. *AMsgPassing* is this.m2(this,this);

% java B
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in SubB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

Method dispatch (17)

5. *AMsgPassing* is SuperB o = new SubB(); o.m2(new B(),new B());

% java B
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in SubB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SuperB x,SuperB y) in SubB;m2(SuperB x,SuperB y) in B;m2(SuperB x,SuperB y) in SuperB;

6. *AMsgPassing* is SuperB o1 = new SubB(); o1.m2(new SSuperB(),new B());

% java B
m1(SuperB x) in SuperB;m2(SSuperB x,SSuperB y) in SSuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SSuperB x,SSuperB y) in SSuperB;

Method dispatch (18)

7. *AMsgPassing* is this.m2(new SSuperB(),new B());

% java B
m1(SuperB x) in SuperB;m2(SSuperB x,SSuperB y) in SSuperB;

% java SubB
m1(SuperB x) in SuperB;m2(SSuperB x,SSuperB y) in SSuperB;

8. *AMsgPassing* is this.m2(new Object(),new B());

javac complains.

Inner class/interface

Classes & interfaces can be declared inside a class; called inner classes & interfaces.

```
public class NestedClass {
  private interface MyInterface { String m(); }
  private class MyClass implements MyInterface
  { public MyClass() {}
    public String m() { return "MyClass"; } }
  private MyClass o = new MyClass();
  public String m() { return "I have " + o.m() + "."; }  }
```

an inner interface

an inner class

Compiling NestedClass (NestedClass.java), in addition to NestedClass.class, NestedClass$MyInterface.class & NestedClass$MyClass.class are made for the inner interface & class.

Enum type (1)

An enum type is a special class of Java.

```
public enum TokenName { PLUS, MUL, NUM, UNDEF, }
```

instances of TokenName; (called enum constants)
no other instances of TokenName

An enum constant *EC* in an enum type *ET* is refered as *ET.EC*.

```
public String toString() throws IllegalStateException {
  if (this.name == TokenName.PLUS) {  return "plus"; }
  else if (this.name == TokenName.MUL) { return "mul"; }
  else if (this.name == TokenName.NUM) { return "num=" + num; }
  else if (this.name == TokenName.UNDEF) { return "undef:" + undef; }
  else { throw new IllegalStateException("in Token1!"); } }  }
```

checks if all cases are covered at runtime

Enum type (2)

When an enum type *ET* is used in switch, however, an enum constant *EC* should be referred as *EC* instaed of *ET.EC*.

```
public String toString() throws IllegalStateException {
  switch(this.name) {
  case PLUS: return "plus";
  case MUL: return "mul";
  case NUM: return "num=" + num;
  case UNDEF: return "undef:" + undef;
  default: throw new IllegalStateException("in Token2!");  }  }
```

Using an enum type in switch, an inner class is made by javac. This is why Token2$1.class is generated when compiling Token2.java.

Summary

- Method dispatch
- Inner interface/class
- Enum type