Inheritance

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http://softeng.polito.it

Inheritance

- A class can be a sub-type of another class
- The derived class contains
  - all the members of the class it inherits from
  - plus any member it defines explicitly
- The derived class can override the definition of existing methods by providing its own implementation
- The code of the derived class consists of the changes and additions to the base class

Addition

```
class Employee{
   String name;
   double wage;
   void incrementWage(){…}
}
```

```
class Manager extends Employee{
   String managedUnit;
   void changeUnit(){…}
}
```

```
Manager m = new Manager();
m.incrementWage(); // OK, inherited
```

Override

```
class Vector{
   int vect[];
   void add(int x) {…}
}
```

```
class OrderedVector extends Vector{
   void add(int x){…}
}
```


Inheritance and polymorphism

```
class Employee{
 private String name;
 public void print(){
   System.out.println(name);
 }
}
class Manager extends Employee{
  private String managedUnit;

  public void print(){ //override
    System.out.println(name); //un-optimized!
    System.out.println(managedUnit);
  }
}
```

```
Employee e1 = new Employee();
Employee e2 = new Manager();
e1.print(); // name
e2.print(); // name and unit
```

Inheritance and polymorphism

```
Employee e1 = new Employee();
Employee e2 = new Manager(); //ok, is_a
e1.print(); // name
e2.print(); // name and unit
```


Why inheritance

- Frequently, a class is merely a modification of another class. Inheritance minimizes the repetition of the same code
- Localization of code
  - Fixing a bug in the base class automatically fixes it in the subclasses
  - Adding a new functionality in the base class automatically adds it in the subclasses too
  - Less chances of different (and inconsistent) implementations of the same operation

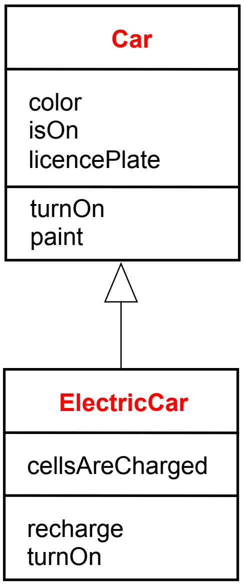
Inheritance terminology

- Class one above
  - Parent class
- Class one below
  - Child class
- Class one or more above
  - Superclass, Ancestor class, Base class
- Class one or more below
  - Subclass, Descendent class

Inheritance in a few words

- Subclass
  - Inherits attributes and methods
  - Can modify inherited attributes and methods (override)
  - Can add new attributes and methods

Inheritance in Java: *extends*




```java
class Car {

  String color;
  boolean isOn;
  String licencePlate;

  void paint(String color) {
    this.color = color;
  }

  void turnOn() {
    isOn=true;
  }
}
```

```java
class ElectricCar extends Car
{

  boolean cellsAreCharged;

  void recharge() {
    cellsAreCharged = true;
  }

  void turnOn() {
    if(cellsAreCharged )
      isOn=true;
  }
}
```


ElectricCar

- Inherits
  - attributes (color, isOn, licencePlate)
  - methods (paint)
- Modifies (overrides)
  - turnOn()
- Adds
  - attributes (cellsAreCharged)
  - Methods (recharge)

VISIBILITY (SCOPE)

Example

```
class Employee {
  private String name;
  private double wage;
}

class Manager extends Employee {

  void print() {
    System.out.println("Manager" +
                              name + " " + wage);
  }
}
```

Not visible

Protected

- Attributes and methods marked as
  - public are always accessible
  - private are accessible from within the declaring class only
  - protected are accessible from within the class and its subclasses

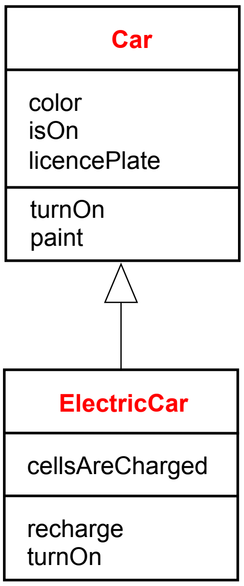
In summary

	Method in the same class	Method of another class in the same package	Method of subclass	Method of class in other package
`private`	✓			
package	✓	✓		
`protected`	✓	✓	✓	
`public`	✓	✓	✓	✓

Super (reference)

- "**this**" is a reference to the current object
- "**super**" is a reference to the parent class

Example




```
class Car {

  String color;
  boolean isOn;
  String licencePlate;

  void paint(String color) {
    this.color = color;
  }

  void turnOn() {
    isOn=true;
  }
}
```

```
class ElectricCar extends Car{

  boolean cellsAreCharged;

  void recharge() {
    cellsAreCharged = true;
  }

  void turnOn() {
    if( cellsAreCharged )
      super.turnOn();
  }
}
```

was

```
if(cellsAreCharged)
  isOn = true;
```

Attributes redefinition

```
▪ Class Parent{
     protected int attr = 7;
  }
▪ Class Child{
     protected String attr = "hello";

     void print(){
       System.out.println(super.attr);
       System.out.println(attr);
     }

     public static void main(String args[]){
        Child c = new Child();
        c.print();
     }
  }
```


INHERITANCE AND CONSTRUCTORS

Construction of child’s objects

- Since each object “contains” an instance of the parent class, the latter must be initialized
- Java compiler automatically inserts a call to default constructor (w/o parameters) of the parent class
- The call is inserted as the first statement of each child constructor

Construction of child objects

- Execution of constructors proceeds top-down in the inheritance hierarchy
- In this way, when a method of the child class is executed (constructor included), the super-class is completely initialized already

Example

```
class ArtWork {
  ArtWork() {
    System.out.println("ctor ArtWork"); }
}
```

```
class Drawing extends ArtWork  {
  Drawing() {
    System.out.println("ctor Drawing"); }
}
```

```
class Cartoon extends Drawing {
  Cartoon() {
    System.out.println("ctor Cartoon"); }
}
```


Example (cont'd)

```
Cartoon obj = new Cartoon();
```

```
ctor ArtWork
ctor Drawing
ctor Cartoon
```

A word of advice

- Default constructor “disappears” if custom constructors are defined

```
class Parent{
  Parent(int i){}
}
class Child extends Parent{ }
// error!
```

```
class Parent{
  Parent(int i){}
  Parent(){} //explicit default
}
class Child extends Parent { }
// ok!
```


Super

- If you define custom constructors with arguments
- and default constructor is not defined explicitly

➔ the compiler cannot insert the call automatically
  - The arguments cannot be inferred

Super

- The child class constructor must call the right constructor of the parent class, explicitly
- Use **super()** to identify constructors of parent class
- Must be the first statement in child constructors

Example

```
class Employee {
  private String name;
  private double wage;
      ???
  Employee(String n, double w){
    name = n;
    wage = w;
  }
}
```

```
class Manager extends Employee {
  private int unit;

  Manager(String n, double w, int u) {
    super();  ERROR !!!
    unit = u;
  }
}
```

Example

```
class Employee {
  private String name;
  private double wage;

  Employee(String n, double w){
    name = n;
    wage = w;
  }
}
```

```
class Manager extends Employee {
  private int unit;

  Manager(String n, double w, int u) {
    super(n,w);
    unit = u;
  }
}
```


Depth of Inheritance Tree

- In general too deep inheritance trees put at risk the understandability of the code
  - An empirical limit is 5 levels

Final method

- The keyword **`final`** applied to a method makes it not overridable by subclasses
  - When methods must keep a predefined behavior
  - E.g. method provide basic service to other methods

POLYMORPHISM AND DYNAMIC BINDING

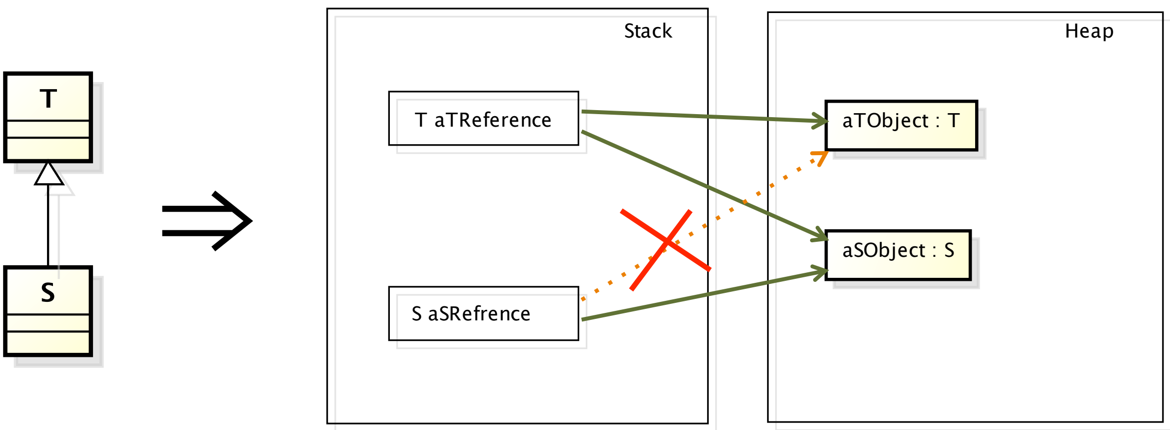
Polymorphism

- A reference of type T can point to an object of type S if-and-only-if
  - S is T or
  - S is a subclass of T

```
Car myCar;
myCar = new Car();
myCar = new ElectricCar();
```


Substitutability principle

- If S is a subtype of T, then objects of type T may be replaced with objects of type S
  - A.k.a. Liskov Substitution Principle (LSP)



Polymorphism

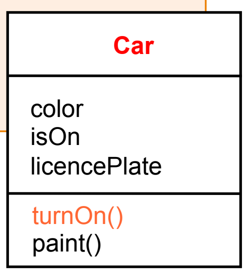
```
Car[] garage = new Car[4];
garage[0] = new Car();
garage[1] = new ElectricCar();
garage[2] = new ElectricCar();
garage[3] = new Car();
for(Car a : garage){
   a.turnOn();
}
```


Static type checking

- The compiler performs a check on method invocation on the basis of the reference type

```
for(Car a : garage){
  a.turnOn();
}
```

Does the type of **a** (i.e. **Car**) provide method **turnOn()**?

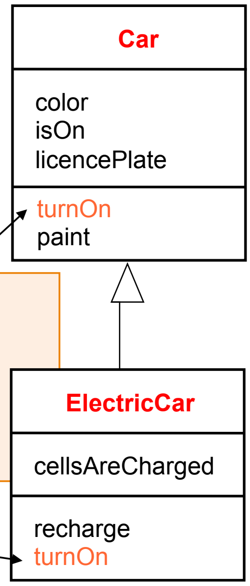


Dynamic Binding

- Association message - method
  - Performed by JVM at run-time
- Constraint
  - Same signature

```
for(Car a : garage){
   a.turnOn();
}
```

message methods



Dynamic binding procedure

- The VM retrieves the actual class of the target object
- If the class contains the invoked method it is execute
- Otherwise the parent class is considered and the previous step is repeated
- The procedure is guaranteed to terminate
  - The compiler checks the reference type class (a base of the actual one) define the method

Why dynamic binding

- Several objects from different classes, sharing a common ancestor class
- Can be treated uniformly
- Algorithms can be written for the base class (using the relative methods) and applied to any subclass

CASTING

Types

- Java is a strictly typed language, i.e., each variable has a type

```
float f;
f = 4.7;    // legal
f = "string"; // illegal
Car c;
c = new Car();  // legal
c = new String(); // illegal
```

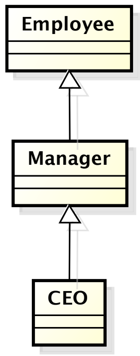

Cast

- Type conversion
  - explicit or implicit

```
int i = 44;
float f = i;
// implicit cast 2c -> fp
f = (float) 44;
// explicit cast
```

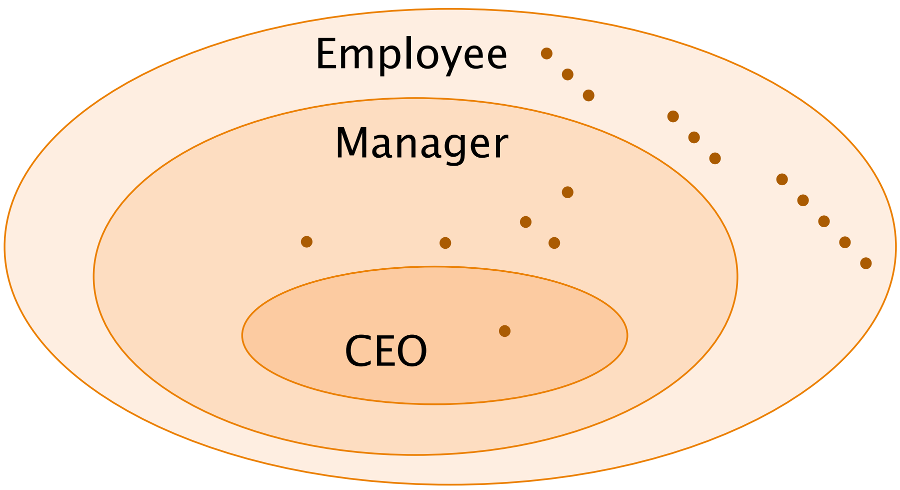
Cast – Generalization

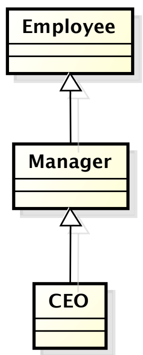
- Things change slightly with inheritance
- Normal case…




```
Employee e = new Employee("Smith",12000);
Manager m = new Manager("Black",25000,"IT");
```


Generalization





Upcast

- Assignment from a more specific type (subtype) to a more general type (supertype)
  - ```
    Employee e = new Employee(…);
    Manager m = new Manager(…);
    Employee em = m
    ```
  - $\forall$ m $\in$ Manager : m $\in$ Employee
- Upcasts are always type-safe and are performed implicitly by the compiler
  - Though it is legal to explicitly indicate the cast

Upcast

- Motivation
  - You can treat indifferently object of different classes, provided they inherit from a common class

```
Employee[] team = {
  new Manager("Mary Black",25000,"IT"),
  new Employee("John Smith",12000),
  new Employee("Jane Doe",12000)
};
```
```

Cast

- Reference type and object type are distinct concepts
- A reference cast only affects the reference
  - In the previous example the object referenced to by '**`em`**' continues to be of Manager type
- Notably, in contrast, a primitive type cast involves a value conversion

Downcast

- Assignment from a more general type (super-type) to a more specific type (sub-type)
  - **`Manager mm = (Manager)em;`**
  - $\exists$ em $\in$ Employee : em $\in$ Manager
  - $\exists$ em $\in$ Employee : em $\notin$ Manager
- Not safe by default, no automatic conversion provided by the compiler
  - MUST be explicit

Downcast

- Motivation
  - To access a member defined in a class you need a reference of that class type
    - Or any subclass

```
Employee emp = staff[0];
s = emp.getDepartment();
Manager mgr = (Manager)staff[0];
s = mgr.getDepartment();
```

Syntax Error: The method getDepartment() is undefined for the type Employee

Downcast – Warning

- The compiler trusts any downcast
- The JVM at run-time checks type consistency for all reference assignments

```
mgr = (Manager)staff[1];
```

`ClassCastException`: Employee cannot be cast to Manager

Down cast safety

- Use the **`instanceof`** operator

  `aReference instanceof aClass`

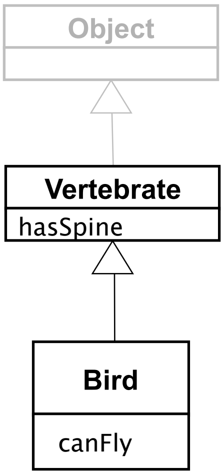
  - Returns true if the object referred to by the reference can be cast to the class
    - i.e. if the object belongs to the given glass or any of its subclasses

```
if(staff[1] instanceof Manager){
   mgr = (Manager)staff[1];
}
```


OBJECT

Class Object

- **`java.lang.Object`**
- All classes are subtypes of Object



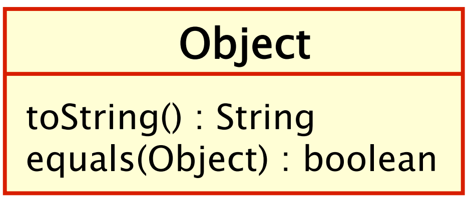
extends Object Implicitly

```
class Vertebrate  {
   …
}
```

```
class Bird extends Vertebrate{
   …
}
```


Class Object

- Each instance can be seen as an Object instance (see Collection)
- Class **`Object`** defines some services, which are useful for all classes
- Often, they are overridden in sub-classes



Objects' collections

- References of type **Object** play a role similar to **void*** in C

```
Object [] objects = new Object[3];
objects[0]= "First!";
objects[2]= new Employee("Luca","Verdi");
objects[1]= new Integer(2);
for(Object obj : objects){
  System.out.println(obj);
}
```

Wrappers must be used instead of primitive types

Object class methods

- **hashCode()**
  - Returns a unique code
- **toString()**
  - Returns string representation of the object
- **equals()**
  - Checks if two objects have same contents
- **clone()**
  - Creates a copy of the current object
- **finalize()**
  - Invoked by GC upon memory reclamation

Object.toString()

- **`toString()`**
  - Returns a string representing the object contents
  - The default implementation returns:

`ClassName@#hash#`

  - Es:

`org.Employee@af9e22`

Object
toString() : String equals(Object) : boolean

Object.equals()

- **`equals()`**
  - Tests equality of values
  - Default implementation compares references:

```
public boolean equals(Object other){
return this == other;
}
```

  - Must be overridden to compare contents, e.g.:

```
public boolean equals(Object o){
Student other = (Student)o;
return this.id.equals(other.id);
}
```

Object
toString() : String equals(Object) : boolean

The equals() Contract

- It is reflexive: **`x.equals(x) == true`**
- It is symmetric: **`x.equals(y)==y.equals(x)`**
- It is transitive: for any reference values x, y and z
- if **`x.equals(y)==true && y.equals(z)==true`** => **`x.equals(z)==true`**
- It is **consistent**: for any reference values x and y, multiple invocations of **`x.equals(y)`** consistently return true (or false), provided that no information used in equals comparisons on the object is modified.
- **`x.equals(null) == false`**

The hashCode() contract

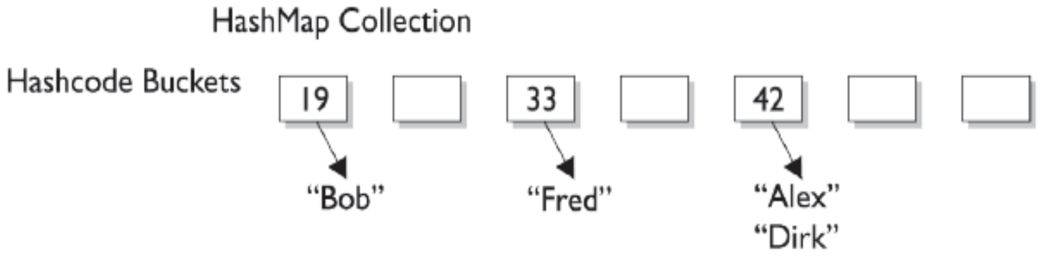
- The **`hashCode()`** method must consistently return the same value, if no information used in **`equals()`** comparisons on the object is modified.
- If two objects are equal for **`equals()`** method, then calling the **`hashCode()`** method on the two objects must produce the same integer result.
- If two objects are unequal for **`equals()`** method, then calling the **`hashCode()`** method on the two objects *may* produce distinct integer results.
  - producing distinct results for unequal objects may improve the performance of hash tables

hashCode() vs. equals()

Condition	Required	Not Required (but allowed)
`x.equals(y) == true`	`x.hashCode() == y.hashCode()`	
`x.hashCode() == y.hashCode()`		`x.equals(y)==true`
`x.equals(y) == false`		-
`x.hashCode() != y.hashCode()`	`x.equals(y)==false`	

hashCode example

Key	Hashcode Algorithm	Hashcode
Alex	A(1) + L(12) + E(5) + X(24)	= 42
Bob	B(2) + O(15) + B(2)	= 19
Dirk	D(4) +I(9) + R(18) + K(11)	= 42
Fred	F(6) + R(18) + E(5) + (D)	= 33



System.out.print(Object)

- **`print`** methods implicitly invoke **`toString()`** on all object parameters

```
class Car{ String toString(){…} }
Car c = new Car();
System.out.print(c);  // same as...
... System.out.print(c.toString());
```

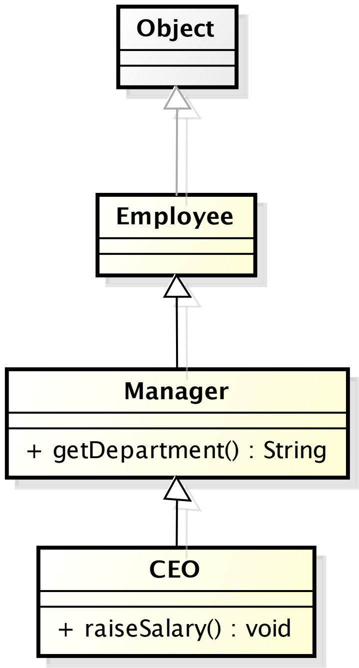
- Polymorphism applies when **`toString()`** is overridden

```
Object ob = c;
System.out.print(ob);//Car's toString() called
```


Variable arguments- example

```
static void plst(String pre, Object...args){
    System.out.print(pre);
    for(Object o:args){
      if(o!=args[0]) System.out.print(", ");
      System.out.print(o);
    }
   System.out.println();
}
public static void main(String[] args) {
  plst("List:","A",'b',123, "ciao");
}
```

Company Employees



Upcast to Object

- Each class is either directly or indirectly a subclass of **`Object`**
- It is always possible to upcast any instance to Object type (see Collection)

```
AnyClass foo = new AnyClass();
Object obj;
obj = foo;
```

ABSTRACT CLASSES

Abstract class

- Often, a superclass is used to define common behavior for many children classes
- But the class is too general to be instantiated
- The behavior is left partially unspecified
  - this is more concrete than interface

Abstract modifier

```
public abstract class Shape {

   private int color;

   public void setColor(int color){
      this.color = color;
   }

   // to be implemented in child classes
   public abstract void draw();
}
```

No method body

Abstract modifier

```
public class Circle extends Shape {

   public void draw() {
      // body goes here
   }
}


Object a = new Shape();  // Illegal: abstract
Object a = new Circle(); // OK: concrete
```

Sorter

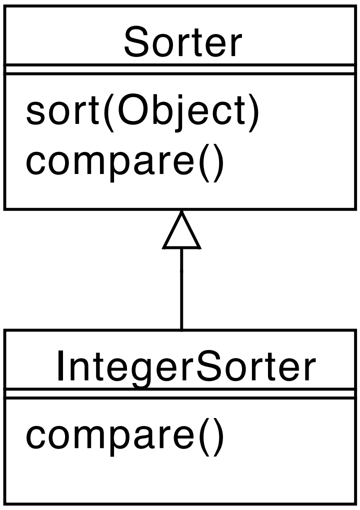
```
class Sorter {
  public void sort(Object v[]){
    for(int i=1; i<v.length; ++i)
      for(int j=1; j<v.length; ++j){
        if(compare(v[j-1],v[j])>0)
          Object o=v[j];
          v[j]=v[j-1]; v[j-1]=o;
      }
  }
  virtual void compare(Object a, Object b);
}
```


StringSorter

```
class StringSorter extends Sorter {
  void compare(Object a, Object b){
    String sa=(String)a;
    String sb=(String)b;
    return sa.compareTo(sb)>0;
  }
}
```

```
Sorter ssrt = new StringSorter();
String v={"g","t","h","n","j","k"};
ssrt.sort(v);
```

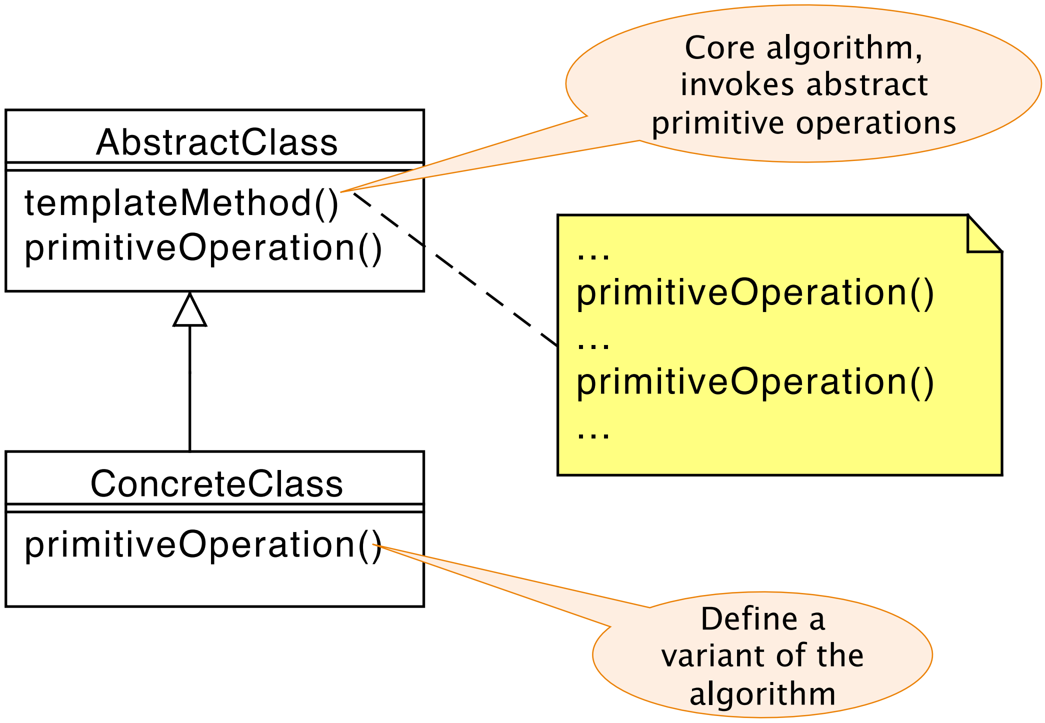
Template Method Example



Template Method Pattern

- Context:
  - An algorithm/behavior has a stable core and several variation at given points
- Problem
  - You have to implement/maintain several almost identical pieces of code

Template Method



INTERFACES

Java interface

- An interface is a special type of class where methods and attributes are implicitly public
  - Attributes are implicitly static and final
  - Methods are implicitly abstract (no body)

- Cannot be instantiated (no **new**)
- Can be used as type for references

Interfaces and inheritance

- An interface can extend another interface, cannot extend a class

```
interface Bar extends Comparable {
  void print();
}
```

interface

- An interface can extend multiple interfaces

```
interface Bar extends Orderable, Comparable{
  ...
}
```

interfaces

Class implementations

- A class can extend only one class
- A class can implement multiple interfaces

```
class Person
    extends Employee
    implements Orderable, Comparable {…}
```


Purpose of interfaces

- Define a common "interface" that allows alternative implementations
- Provide a (set of) method(s) that can be called by algorithms
  - Provide a common behavior
- Behavioral parameterization
  - Strategy pattern
- Define a (set of) callback method(s)
  - Observer pattern

Alternative implementations

- Complex numbers

```
public interface Complex {
  double real();
  double imaginary();
  double modulus();
  double argument();
}
```

- Can be implemented using either Cartesian or polar coordinates

Common behavior: sorting

- Class **java.utils.Arrays** provides the static method **sort()**

```
int[] v = {7,2,5,1,8,5};
Arrays.sort(v);
```

- Sorting object arrays requires a way to compare two objects:
  - **java.lang.Comparable**

Comparable

- Interface **java.lang.Comparable**

```
public interface Comparable{
  int compareTo(Object obj);
}
```

- Semantics: returns
  - a negative integer if **this** precedes **obj**
  - 0, if **this** equals **obj**
  - a positive integer if **this** succeeds **obj**

Note: simplified version, actual declaration uses generics

Comparable

```
public class Student
      implements Comparable {
  int id;
  public int compareTo(Object o){
    Student other = (Student)o;
    return this.id - other.id;
  }
}
```

Common behavior: iteration

- Interface **java.lang.Iterable**

```
public interface Iterable {
  Iterator iterator();
}
```

- The class implementing `Iterable` can be the target of a *foreach* construct
  - Use the Iterator interface

Note: simplified version, actual declaration uses generics

Common behavior: iteration

- Interface **java.util.Iterator**

```
public interface Iterator {
  boolean hasNext();
  Object next();
}
```

- Semantics:
  - Initially before the first element
  - `hasNext()` tells if a next element is present
  - `next()` returns the next element and advances by one position

Note: simplified version, actual declaration uses generics

Iterable example

```
class Random implements Iterable {
  private int[] values;
  public Random(int n, int min, int max){ … }
  class RIterator implements Iterator {
    private int next=0;
    public boolean hasNext() {
        return next < values.length; }
    public Object next() {
        return new Integer(values[next++]);}
  }
  public Iterator iterator() {
    return new RIterator();
  }
}
```


Iterable example

- Usage of an iterator with for-each

```
Random seq = new Random(10,5,10);
for(Object e : seq){
  int v = ((Integer)e).intValue();
  System.out.println(v);
}
```

Inheritance vs. Duck typing

When I see a bird that walks like a duck and swims like a duck and quacks like a duck, I call that bird a duck

- Duck typing
  - Method invocation correctness check is performed at run-time
  - Invocation is correct if the actual class of the target object provides the required method (directly or inherited)
  - Dynamic binding can result into an error

Behavioral parameterization

```
void process(Object[] v, Processor p){
  for(Object o : v){
    p.handle(o);
  }
}
```

```
public interface Processor{
  void handle(Object o);
}
```

```
String[] v = {"A", "B", "C", "D"};
Processor printer = new Printer();
process(v,printer);
```

```
public class Printer
implements Processor{
  public void handle(Object o){
    System.out.println(o);
}}
```

Behavioral parameterization

```
void process(Object[] v, Processor p){
  for(Object o : v){
    p.handle(o);
  }
}
```

```
public interface Processor{
  void handle(Object o);
}
```

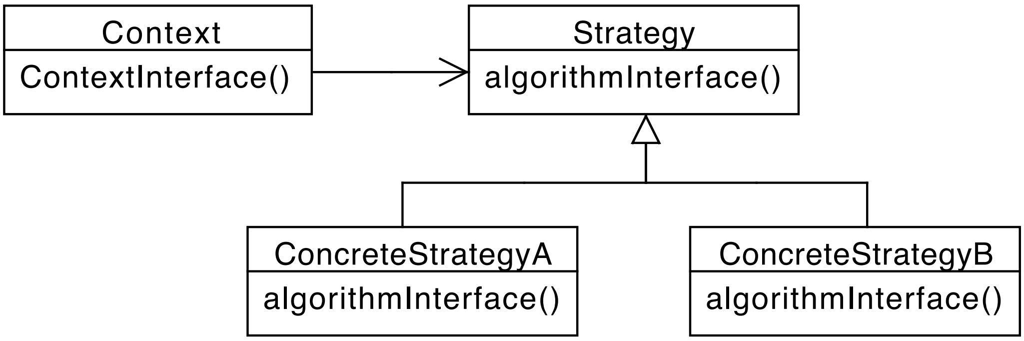
```
String[] v = {"A", "B", "C", "D"};
Processor printer = new Processor(){
  public void handle(Object o){
    System.out.println(o);
  }};
process(v,printer);
```

Anonymous inner class

Strategy Pattern

- Context
  - Many classes or algorithm has a stable core and several behavioral variations
- Problem
  - Several different implementations are needed.
  - Multiple conditional constructs tangle the code.

Strategy Pattern



Comparator

- Interface **`java.util.Comparator`**

```
public interface Comparator{
   int compare(Object a, Object b);
}
```

- Semantics (as comparable): returns
  - a negative integer if **`a`** precedes **`b`**
  - 0, if **`a`** equals **`b`**
  - a positive integer if **`a`** succeeds **`b`**

Note: simplified version, actual declaration uses generics

Comparable

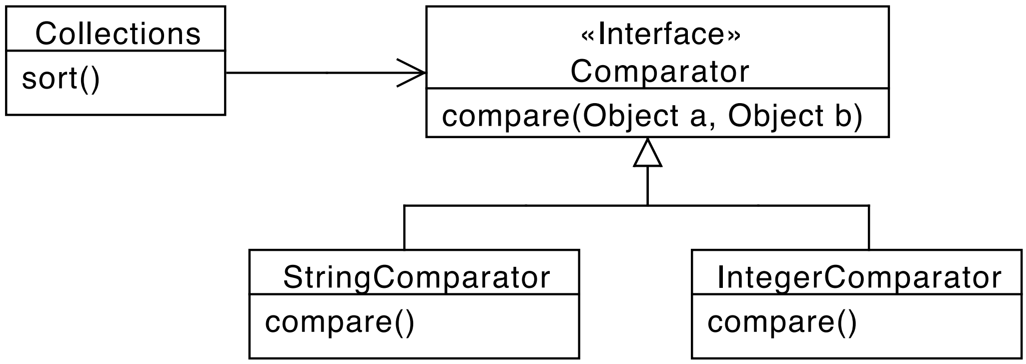
```
public class StudentCmp implements Comparator{
  public int compare(Object a, Object b){
    Student sa = (Student)a;
    Student sb = (Student)b;
    return a.id - b.id;
  }
}
```

```
Student[] sv = {new Student(11),
                new Student(3),
                new Student(7)};
Arrays.sort(sv, new StudentCmp());
```


Comparator w/anonymous cls

```
Student[] sv = {new Student(11),
                 new Student(3),
                 new Student(7)};
Arrays.sort(sv, new Comparator(){
  public int compare(Object a, Object b){
    Student sa = (Student)a;
    Student sb = (Student)b;
    return a.id - b.id;
}}
);
```

Strategy Example



Strategy Consequences

+ Avoid conditional statements
+ Algorithms may be organized in families
+ Choice of implementations
+ Run-time binding
- Clients must be aware of different strategies
- Communication overhead
- Increased number of objects

A word of advice

- Defining a class that contains abstract methods only is not illegal but..
  - You should use interfaces instead
- Overriding methods in subclasses can maintain or extend the visibility of overridden superclass's methods
  - e.g. protected int m() can't be overridden by
    - private int m()
    - int m()
  - Only protected or public are allowed

Default methods

- Interface method implementation can be provided for **`default`** methods
  - Cannot refer to non static attributes
    - Since they are unknown to the interface
  - Can refer to arguments and other methods
  - Can be overridden as usual methods

Default methods motivation

- Enable adding new functionality to the interfaces of libraries and ensure compatibility with code written for older versions of those interfaces.
- Provide extra functionalities through multiple inheritance

FUNCTIONAL INTERFACES

Functional interface

- Interface containing only one method
  - E.g. **`java.lang.Comparator`**
- The semantics is purely functional
  - The outcome of the method is based solely on the arguments
  - There are no side-effects on attributes
- Predefined interfaces are defined in
  - **`java.util.function`**
  - Specific for different primitive types
  - Generic version (see Generics)

Functions (int versions)

- Function
  - **`R apply(int value)`**
- Consumer
  - **`void accept(int value)`**
- Predicate
  - **`boolean test(int value)`**
- Supplier
  - **`int getAsInt()`**
- BinaryOperator
  - **`int applyAsInt(int left, int right)`**

Lambda function

- Simplified syntax to define anonymous inner class instances for functional interfaces

```
printer =
            o -> System.out.println(o);
```

```
Processor printer = new Processor(){
  public void handle(Object o){
    System.out.println(o);
  }};
```


Lambda expression syntax

parameters **->** *body*

- Parameters
  - None: **()**
  - One: **x**
  - Two or more: **(x, y)**
  - Types can be omitted
    - Inferred from assignee reference type
- Body
  - Expression: **x + y**
  - Code Block: **{ return x + y; }**

Type inference

- Lambda parameter types are usually omitted
  - Compiler can infer the correct type from the context
  - Typically they match the parameter types of the only method in the functional interface

Comparator w/lambda

```
Arrays.sort(sv,
  (a,b) -> ((Student)a).id -((Student)b).id
);
```

Vs.

```
Arrays.sort(sv,new Comparator(){
 public int compare(Object a, Object b){
   return ((Student)a).id -((Student)b).id;
 }});
```

Method reference

- Represent a compact representation of an instance of a functional interface that invoke single method.

```
printer = System.out::println;
```

Equivalent to:
```
o -> System.out.println(o);
```


Method reference syntax

```
Container::methodName
```

Kind	Example
Static method	`Class::staticMethodName`
Instance method of a particular object	`object::instanceMethodName`
Instance method of an arbitrary object of a particular type	`Type::methodName`
Constructor	`Class::new`

Static method reference

- Similar to C function
- The parameters are the same as the method parameters

```
DoubleSupplier generator = Math::random;
generator.getAsDouble();
```

```
package java.util.functions;
interface DoubleSupplier {
  double getAsDouble();
}
```


Instance method of object

- Method is invoked on the specific object
- Parameters are those of the method

```
String hexDigits = "0123456789ABCDEF";
Radix hex = hexDigits::charAt;
System.out.println("Hex for 10 : "
                         + hex.convert(10) );
```

```
interface Radix {
  char convert(int value);
}
```

Instance method reference

- The first parameter is the object on which the method is invoked
- Remaining parameters are those of the method

```
StringValue f = String::length;
for(String e : v){
  System.out.println(f.apply(e));
}
```

```
interface StringValue {
      int apply(String s);
}
```


Constructor reference

- The return type is a new object
- Parameters are the constructor's parameters

```
IntegerBuilder builder = Integer::new;
Integer i = builder.build(1);
```

```
interface IntegerBuilder{
      int build(int value);
}
```

Wrap-up session

- Inheritance
  - Objects defined as sub-types of already existing objects. They share the parent data/methods without having to re-implement
- Specialization
  - Child class augments parent (e.g. adds an attribute/method)
- Overriding
  - Child class redefines parent method
- Implementation/reification
  - Child class provides the actual behaviour of a parent method

Wrap-up session

- Polymorphism
  - The same message can produce different behavior depending on the actual type of the receiver objects (late binding of message/method)
- Interfaces provide a mechanism for
  - Constraining alternative implementations
  - Defining a common behavior
  - Behavioral parameterization
- Functional interfaces and lambda simplify the syntax for behavioral parameterization