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M2 (b) - Types and Polymorphism

Image Source: https://upload.wikimedia.org/wikipedia/commons/2/2b/Cepaea_nemoralis_active_pair_on_tree_trunk.jpg

Logistics

- Sign up the Lab Test
    - You have to sign up Lab Test 1 by the end of this Friday
    - Reference the instruction on MyCourses
- No lecture next Tuesday

Java `Comparable<T>` Interface

- This interface imposes a total ordering on the objects of each class that implements it.

```
public interface Comparable<T>
{
        int compareTo(T o);
}
```

Generics: mechanism that takes type as parameter

Specification of `Comparable<T>`

- Compares this object with the specified object for order.
- Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.
- Also properties of implementor needs to ensure, for example:

  (x.compareTo(y)>0 && y.compareTo(z)>0) implies x.compareTo(z)>0

Client

```
if(object1.compareTo(object2) >0) /*...*/
```

Implements `Comparable<T>`

```
public interface Comparable<T>
{
        int compareTo(T o);
}
```

```
Collections.sort(aCards);// aCards is a List<Card> instance
```

```
public class Card implements Comparable<Card>
{

 … …


    @Override
    public int compareTo(Card pCard)
    {
    … …   return aRank.compareTo(pCard.aRank);
    }
}
```

Objective of this lecture

- Concepts and Principles:

Class's interface, Separation of concerns

- Programming mechanism:

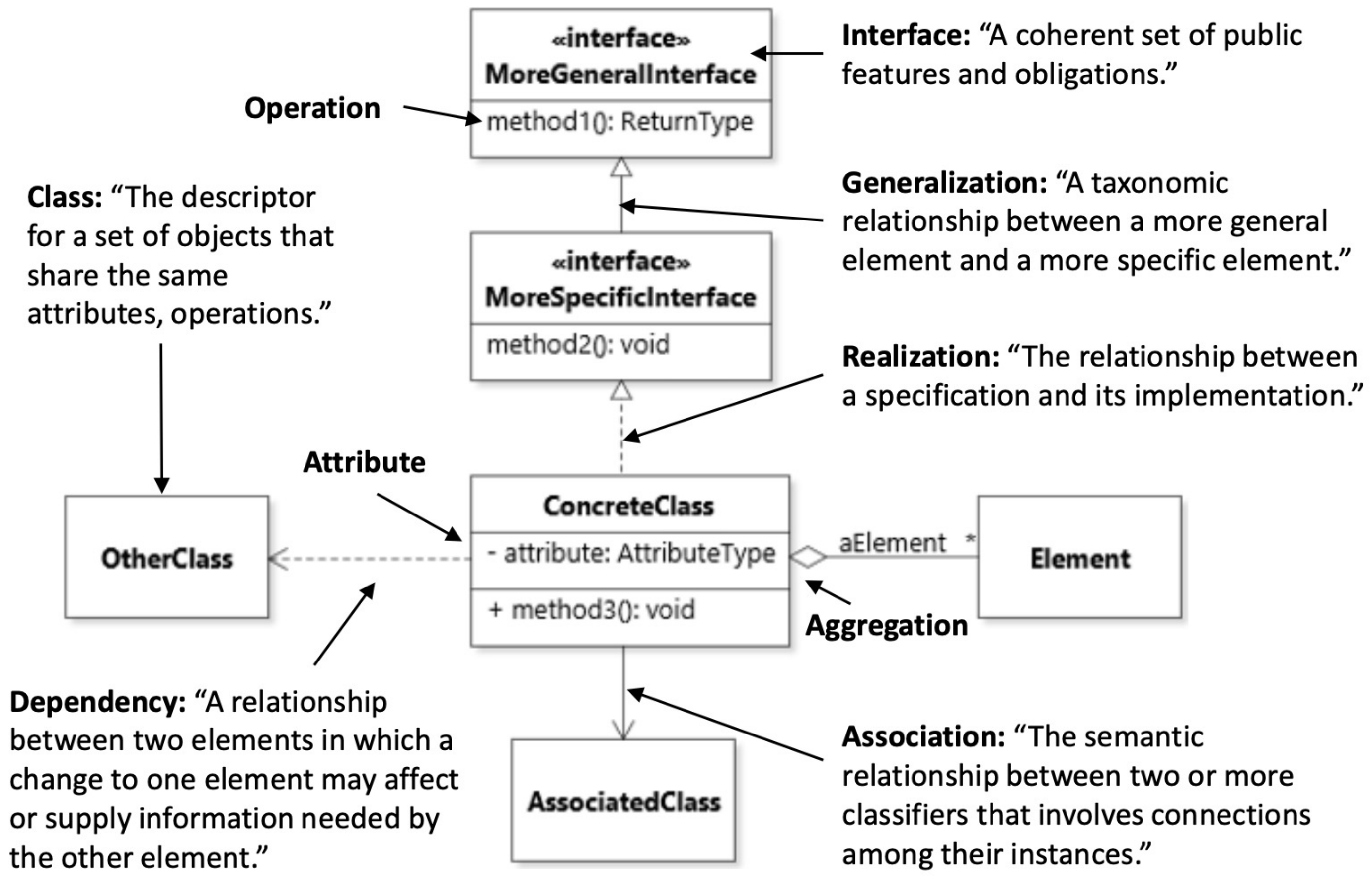
Java Interface type, Subtype polymorphism

- Design techniques:

Interface-based behavior specification, UML Class Diagrams

UML Class Diagram

- Represent Type (mainly classes and interfaces) definitions and relations
- *Static* view (cannot show *run-time* properties)
- Tool: JetUML



Interface: “A coherent set of public features and obligations.”

Generalization: “A taxonomic relationship between a more general element and a more specific element.”

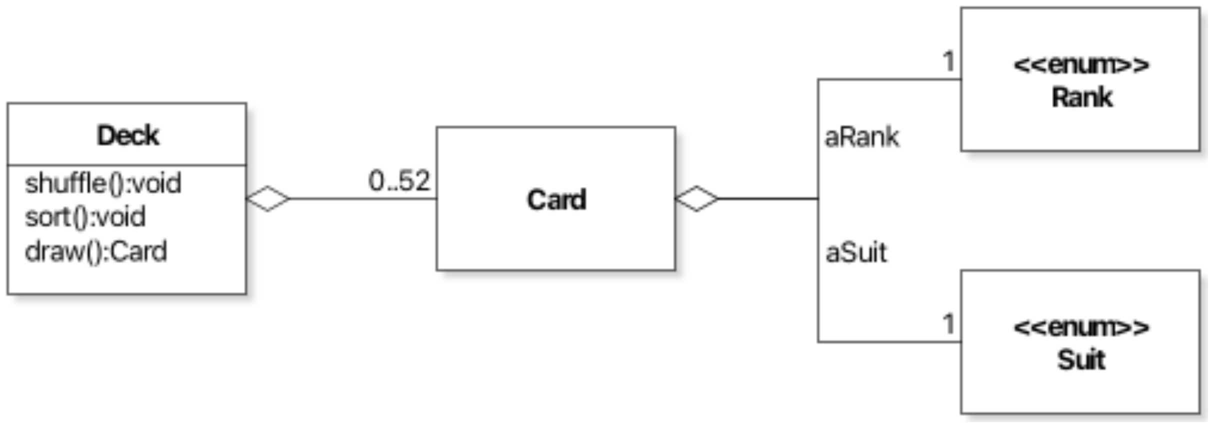
Class: “The descriptor for a set of objects that share the same attributes, operations.”

Realization: “The relationship between a specification and its implementation.”

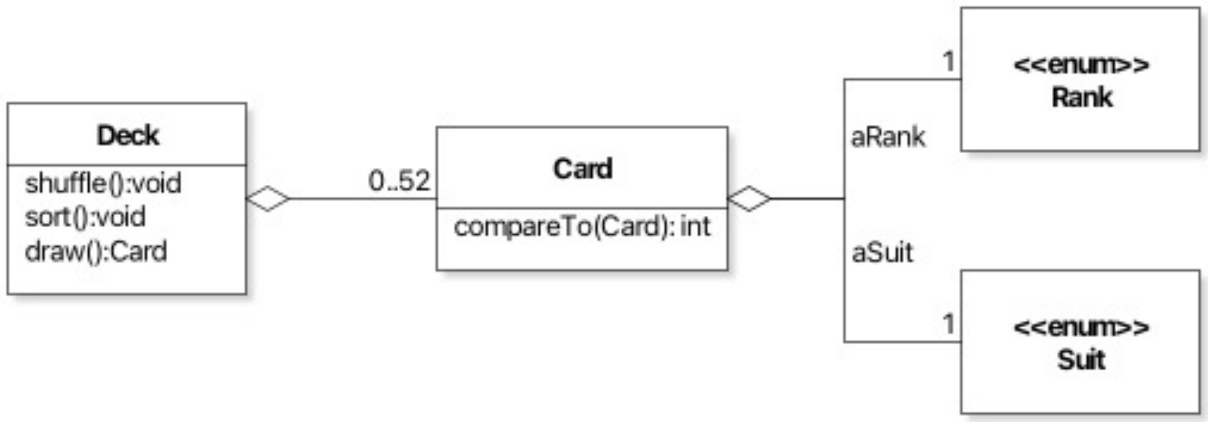
Dependency: “A relationship between two elements in which a change to one element may affect or supply information needed by the other element.”

Association: “The semantic relationship between two or more classifiers that involves connections among their instances.”

Current Design of Deck



Current Design of Deck



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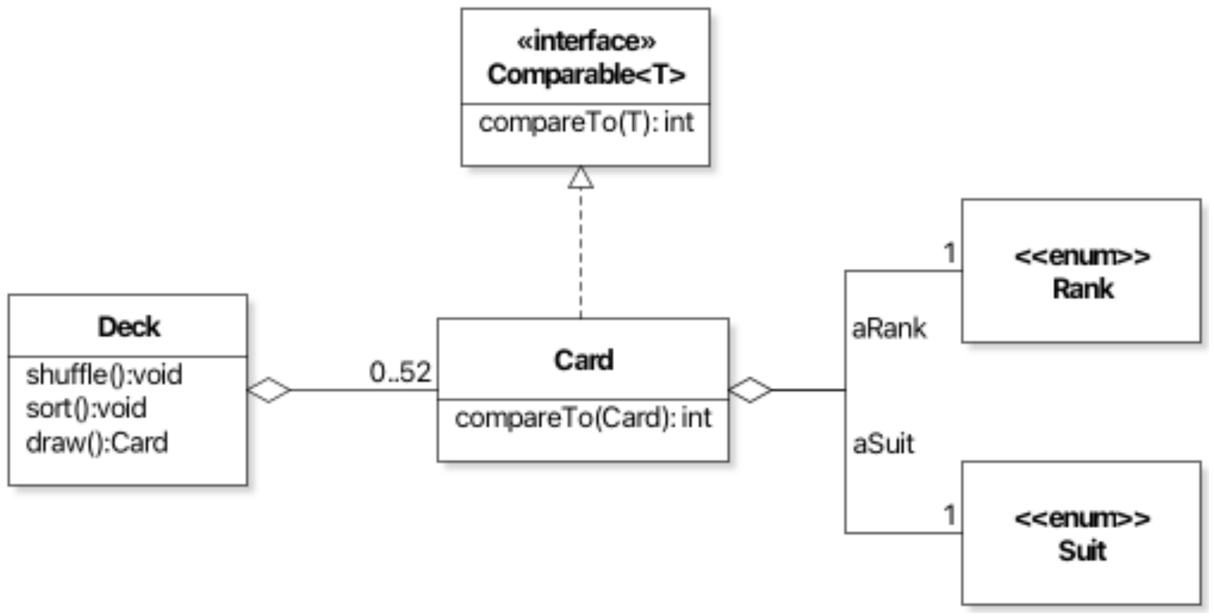
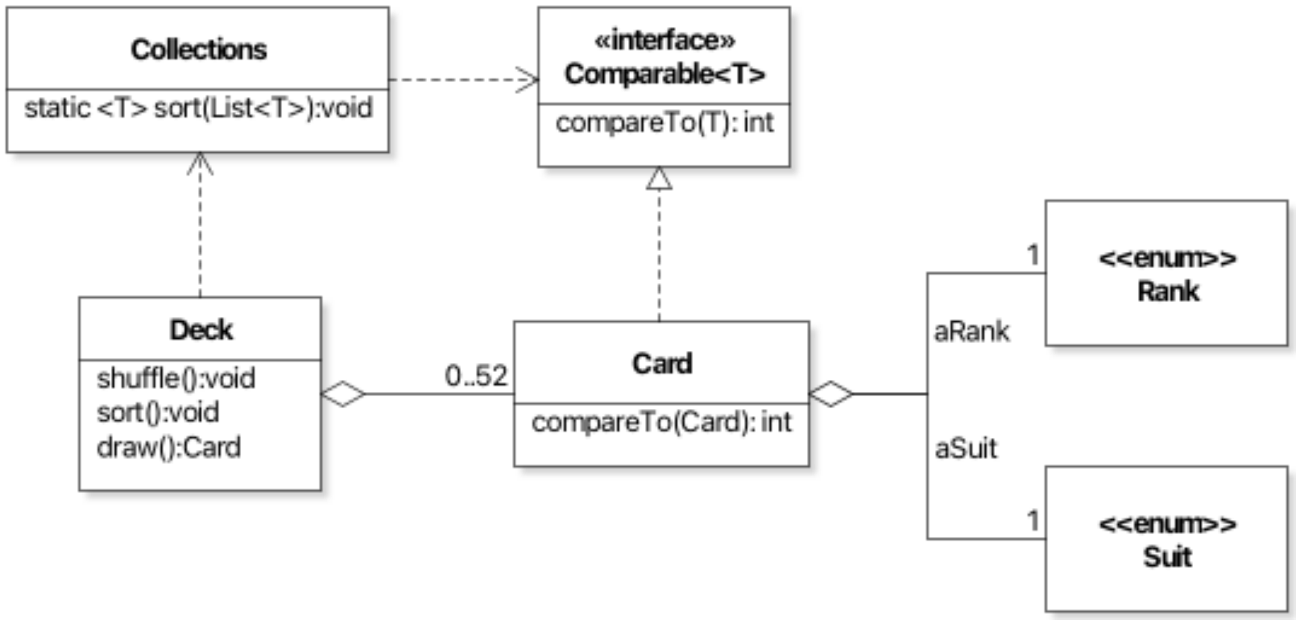


Current Design of Deck



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Separation of Concern

- Concern: anything that matters in providing a solution to a problem
- Prevent information Leakage
- To achieve “orthogonality”: changes in one does not affect any of the others.

Operation on Card Collections

Draw

Add

Remove

Shuffle

Sort

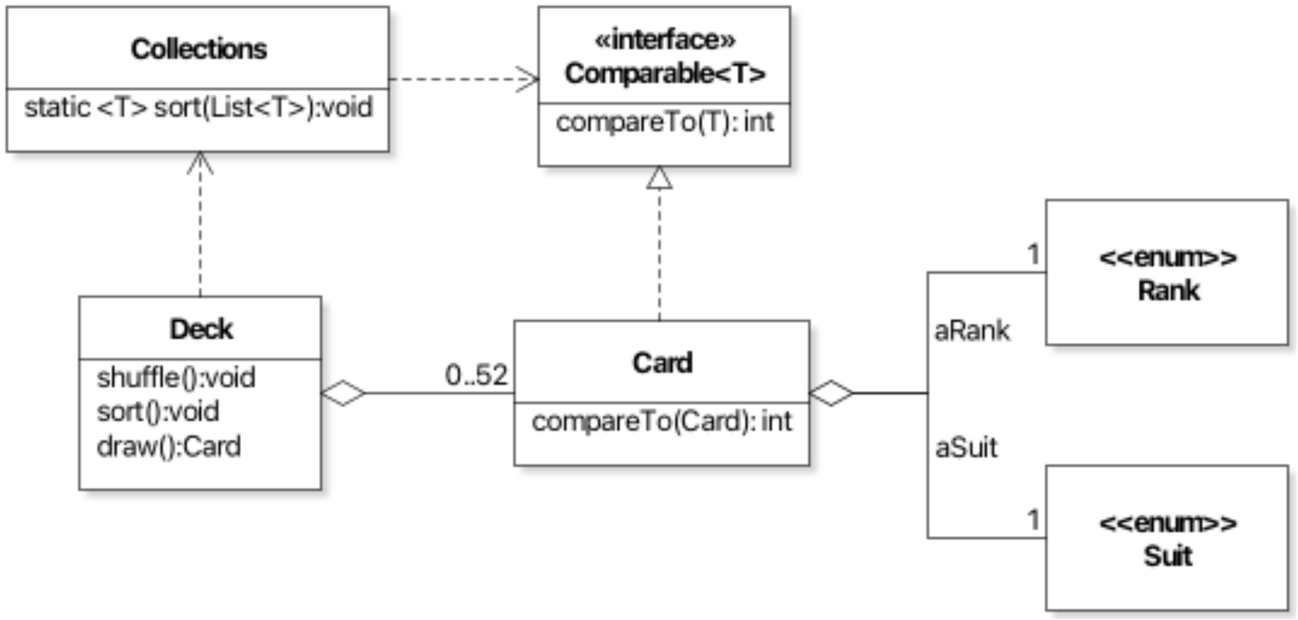
Search

Max/min

Compare
two elements to get
their order or equality

Information leaking
a design knowledge is reflected in many modules

How did this design apply the principle of Separation of Concern?



Summary

- Concepts and Principles:

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- Programming mechanism:

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Objective

- Programming mechanism:

Java Generics, Java Nested Classes

- Patterns and Antipatterns:

STRATEGY, SWITCH Statement 👎

- Design techniques:

Function objects

Java Generics

```
public interface ListOfCard {
    boolean add(Card pElement);
    Card get(int index);
}
```

```
public interface ListOfNumbers {
    boolean add(Number pElement);
    Number get(int index);
}
```

```
public interface ListOfIntegers {
    boolean add(Integer pElement);
    Integer get(int index);
}
```

… …

Java Generics

- Purpose: make the code reusable for many different types

```
    boolean add(Number pElement);
    Number get(int index);
```

$$\downarrow$$

```
public interface List<E> {
    boolean add(E pElement);
    E get(int index);
}
```

Java Generics

```
List<Card>  cards;
```

Type Argument

Generic type invocation(Parameterized Type)

- Generic Types
  - A class or interface whose declaration has one or more type parameter

Convention:

E for Element
K for Key
V for Value
T for Type

Raw Type

Type Parameter/Variable

```
public interface List<E> {
    boolean add(E pElement);
    E get(int index);
}
```

Recall Java `Comparable<T>` Interface

- This interface imposes a total ordering on the objects of each class that implements it.

```
public interface Comparable<T>
{
        int compareTo(T o);
}

public class Card implements Comparable<Card>
{
        @Override
        public int compareTo(Card pCard)
        {
                …
        }

}
```

Activity 1: Design a generic class that represents a pair of objects with the same type.

```
public class Pair<T>
{



}
```

```
public class Pair<T>
{
   final private T aFirst;
   final private T aSecond;

   public Pair(T pFirst, T pSecond)
   {
      aFirst = pFirst;
      aSecond = pSecond;
   }

   public T getFirst() { return aFirst; }
   public T getSecond() { return aSecond; }

}
```

```
Pair<Card> pair =
    new Pair<>(new Card(Rank.FIVE, Suit.CLUBS),
                new Card(Rank.FOUR, Suit.CLUBS));
Card card1 = pair.getFirst();
```

Type Inferred by Compiler

Java Generics

- Generic Method
  - A method that takes type parameters

emptySet method in java.util.Collections:

```
public static <T> Set<T> emptySet()
```

Type Parameter

Between Modifier and Return Type

Activity 2:

Write a static generic method that add elements of Pair in any type to a collection of the same type.

```
public class Pair<T>
{
   final private T aFirst;
   final private T aSecond;

   public Pair(T pFirst, T pSecond)
   {
     aFirst = pFirst;
     aSecond = pSecond;
   }

   public T getFirst() { return aFirst; }
   public T getSecond() { return aSecond; }

}
```

Interface Collection<E>

```
boolean add(E e)
```

Activity 2

Write a generic method that add elements of Pair in any type to a collection of the same type.

```java
/*
* Add the elements of type T stored in Pair to a Collection of Type T
* @pre pair !=null && collection != null
* @pre pair.getFirst()!=null && pair.getSecond()!=null
* @post collection.contains(pair.getFirst()) && collection.contains(pair.getSecond())
*
* @see Pair
*/
static <T> void fromPairToCollection(Pair<T> pair, Collection<T> collection) {
    /* assertion on pre conditions*/
    collection.add(pair.getFirst());
    collection.add(pair.getSecond());
    /* assertion on post conditions*/
}
```

Adding Restriction on Type Variables

```
public class Pair<T>
{
   final private T aFirst;
   final private T aSecond;

   public Pair(T pFirst, T pSecond)
   {
      aFirst = pFirst;
      aSecond = pSecond;
   }

   public T getFirst() { return aFirst; }
   public T getSecond() { return aSecond; }

}
```

Adding Restriction on Type Variables

```
public class Pair<T extends Deck>
{
   final private T aFirst;
   final private T aSecond;

   public Pair(T pFirst, T pSecond)
   {
     aFirst = pFirst;
     aSecond = pSecond;
   }

   public T getFirst() { return aFirst; }
   public T getSecond() { return aSecond; }
   public boolean isTopCardSame()
}  {
       Card topCardInFirst = aFirst.draw();
       Card topCardInSecond = aSecond.draw();
       return topCardInFirst.equals(topCardInSecond);
   }
```

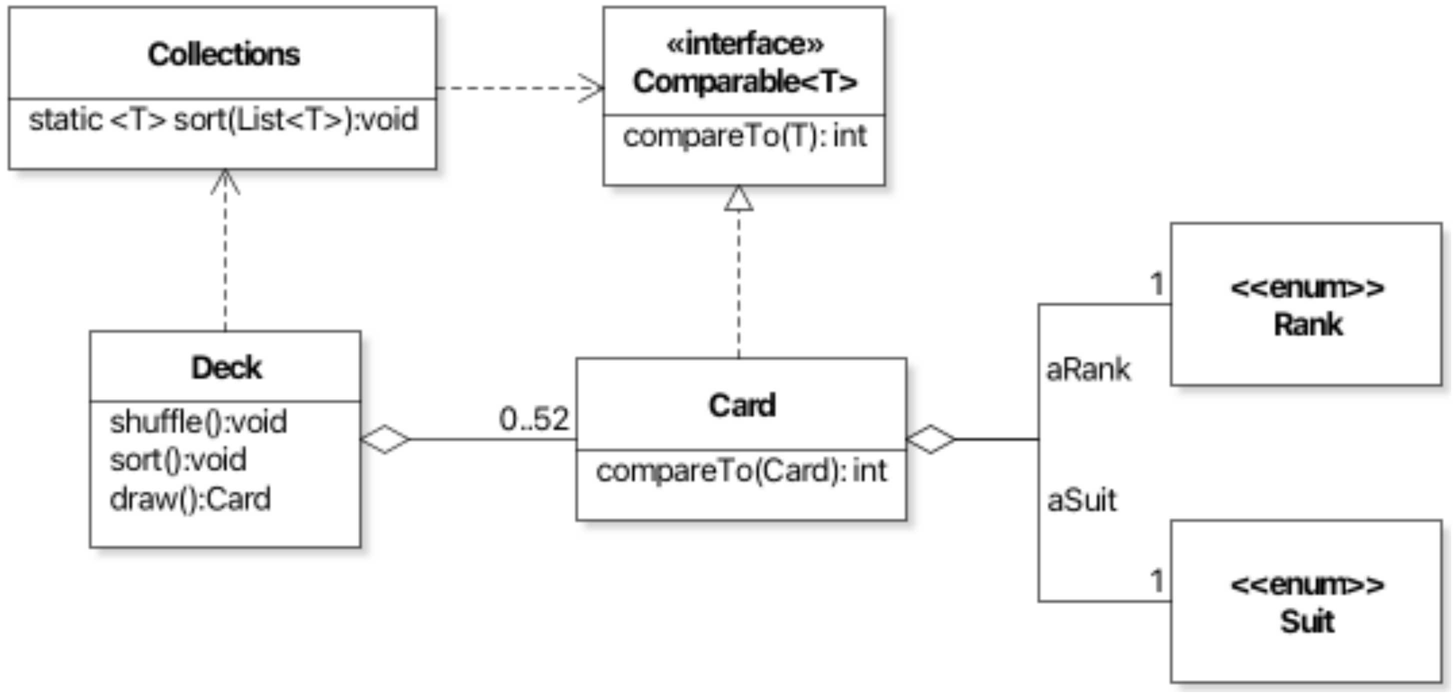
Type can only be Deck or its subtype

call methods of Deck

Generic Method With Type Bound

```
static <T extends Deck>
    void fromPairToCollection(Pair<T> pair, Collection<T> collection) {}
```

Back to the sort method for comparable types



Back to the sort method for comparable types

- In java.util.collections

```
 public static <T extends Comparable<? super T>>  void  sort(List<T> list)
```

```
class Card implements Comparable<Card> {…}

class FancyCard extends Card {…}
```

```
List<FancyCard> fancyCardList = new ArrayList<>();

Collections.sort(fancyCardList);
```

Objective

- Programming mechanism:

Java Generics, Java Nested Classes

- Concepts and Principles:

Separation of concerns;

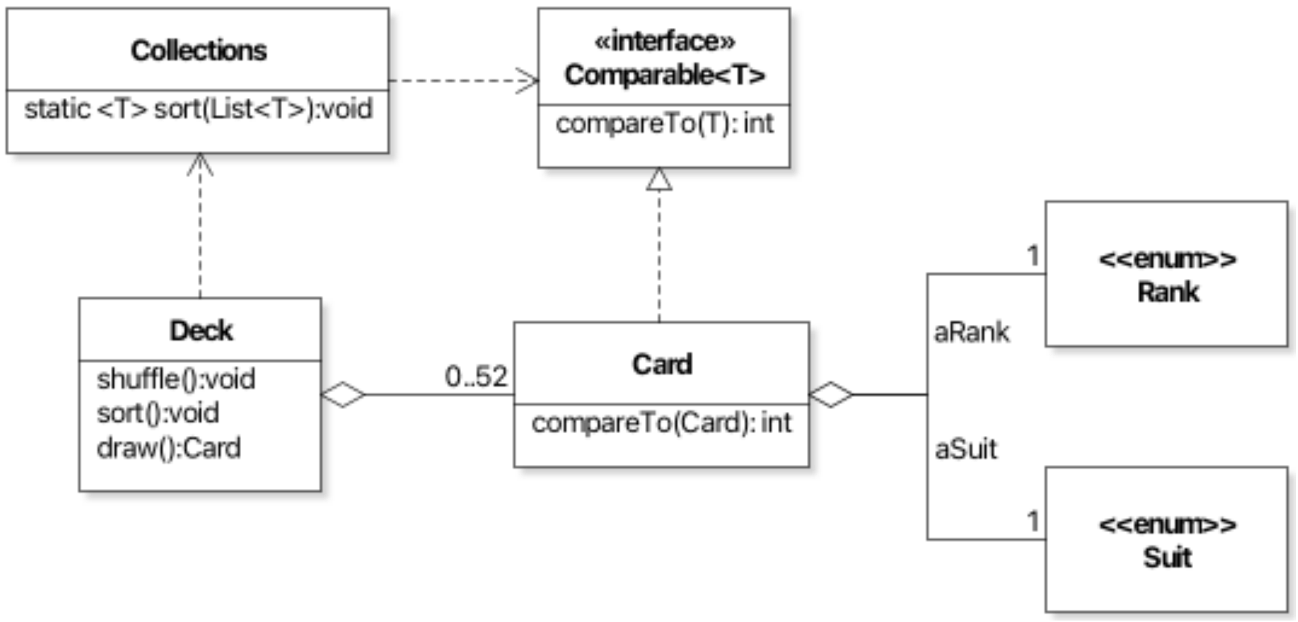
- Patterns and Antipatterns:

STRATEGY, SWITCH Statement 👎

- Design techniques:

Function objects

Current Design of Deck



How to support more than one strategy to compare cards?

Activity 3

Design a UniversalComarator that can compare two cards with more than one strategies including by rank, suit, reversed rank, suit first then rank.

```java
public class UniversalComparator {
    public enum ComparisonStrategy {ByRank, BySuit, ByRankThenSuit}

    ComparisonStrategy aStrategy;
    public UniversalComparator(ComparisonStrategy pStrategy) {
        aStrategy = pStrategy;
    }
    public int compare(Card c1, Card c2) {
        switch (aStrategy) {
            case ByRank:
                return compareByRank(c1, c2);
            case BySuit:
                return compareBySuit(c1, c2);
            case ByRankThenSuit:
                return compareByRankThenSuit(c1, c2);
            default:
                throw new AssertionError(this);
        }
    }

    private int compareBySuit(Card c1, Card c2) {
             …
    }
…}
```

Recall Polymorphism

```
public class Undergrad implements Student

public class Graduate implements Student

public class NonDegreeStudent implements Student

public class VisitingStudent implements Student
```

Polymorphic **Student**

Program to the interface

```
public boolean attendSeminar(Student pStudent)
{
    if(registeredStudents.size()<=cap) {
        registeredStudents.add(pStudent.getID());
        return true;

    }
    return false;
}
```

Can we do the same thing for the compare strategy?

Recall Polymorphism

```
public class ComparatorBySuit implements Comparator

public class ComparatorByRank implements Comparator

public class ComparatorBySuitThenRank implements Comparator

public class ComparatorByRankReverse implements Comparator
```

Polymorphic **Comparator**

Program to the interface

Client

```
public void sort(Comparator pComparator)
{
    …
        if pComparator.compare(card1, card2))

    …
}
```

Java Comparator Interface

- **Interface Comparator<T>**

```
public int compare(T o1, T o2)
```

Compares its two arguments for order. Returns a negative integer, zero, or a positive integer as the first argument is less than, equal to, or greater than the second.

ByRank Comparator

```java
public class ByRankComparator implements Comparator<Card> {

    @Override
    public int compare(Card pCard1, Card pCard2) {
        return pCard1.getRank().compareTo(pCard2.getRank());
    }
}
```

BySuit Comparator

```java
public class BySuitComparator implements Comparator<Card>
{
    @Override
    public int compare(Card pCard1, Card pCard2) {
        return pCard1.getSuit().compareTo(pCard2.getSuit());
    }
}
```

Another sort method provided by Java Collections

- In java.util.collections

```
public static <T> void sort(List<T> list, Comparator<? super T> c)


Collections.sort(aCards, new ByRankComparator());
                 List<Card>
```

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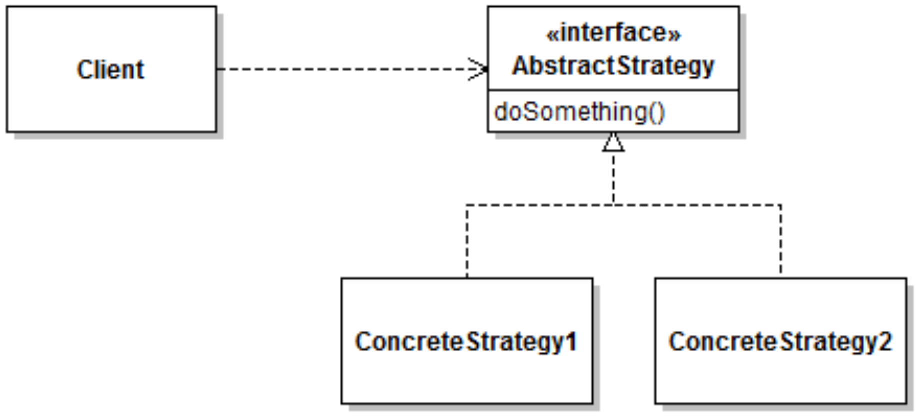
STRATEGY, SWITCH Statement 👎

- Design techniques:

Function objects

Strategy Design Pattern

- Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it.

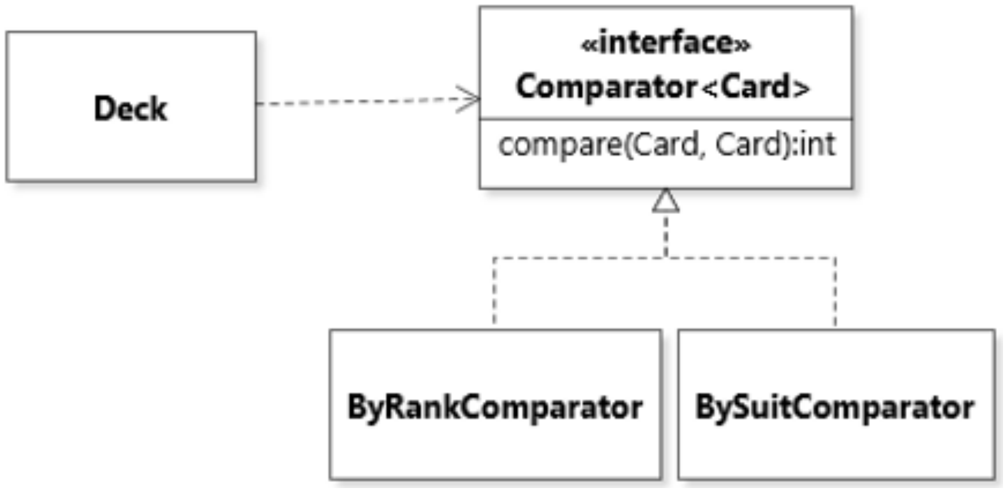


Algorithms are appropriate at different times

New Algorithms need to be introduced when necessary

Strategy Design Pattern

- Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it.



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Function objects

Function Object

- An interface with single abstract method
- The actual function is achieved by the object of a class which implements that interface

Function Object

```
Collections.sort(aCards, new ByRankComparator());
```

- An interface with single abstract method
- The actual function is achieved by the object of a class which implements that interface

Function Object

```
Collections.sort(aCards, new ByRankComparator());
```

- An interface with single abstract method
- The actual function is achieved by the object of a class which implements that interface

Is the function is only used once?

Should the function have state?

Does the function need to access the private field?

Anonymous Class

- An inner class that is declared and instantiated at the same time.

```
class OuterClass
{
    public void method()
    {
        SuperType instance = new SuperType() {
                     … …
         };
    }

}
```

Anonymous Class for Function Object

```java
public class ByRankComparator implements Comparator<Card> {
    @Override
    public int compare(Card pCard1, Card pCard2) {
        return pCard1.getRank().compareTo(pCard2.getRank());
    }

}
```

```java
Collections.sort(aCards, new ByRankComparator());
```

Interface to implement or class to extend

```java
Collections.sort(aCards, new Comparator<Card>() {
    public int compare(Card pCard1, Card pCard2) {
        return pCard1.getRank().compareTo(pCard2.getRank());
    }
});
```

Enable access to the private field

```
public class Card
{
     ……



   public static Comparator<Card> createByRankComparator()
   {
      return new Comparator<Card>()
         {
            @Override
            public int compare(Card pCard1, Card pCard2) {
                  return pCard1.aRank.compareTo(pCard2.aRank);
         }
      };
   }
}
```

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Java Nested Classes

- Classes defined within another class
    - Static member class

$$\left.\begin{array}{l}\bullet\ \text{Non-static member class}\\[1em] \bullet\ \text{Local class}\\[1em] \bullet\ \text{Anonymous class}\end{array}\right\}\ \text{Inner class}$$

Static Member Class

```
class OuterClass {
    ...
    static class StaticMemberClass {
        ...
    }
 }
```

```
OuterClass.StaticMemberClass nestedObject
      = new OuterClass.StaticMemberClass();
```

Non-Static Member Class

```
class OuterClass {
    ...
    class InnerClass {
        ...
    }
}
```

```
OuterClass.InnerClass innerObject =
        outerObject.new InnerClass();
```

Local Class

- An inner class that is defined in a block

```
class OuterClass
{
    public void method()
    {
        class LocalClass implements Supertype {
                ……
        }
        Supertype instance = new LocalClass();
    }

}
```

Anonymous Class

- An inner class that is declared and instantiated at the same time.

```
class OuterClass
{
    public void method()
    {
        SuperType instance = new SuperType() {
                    … …
         };
    }

}
```

Enable access to the private field

```java
public class Card
{
    public static Comparator<Card> createByRankComparator()
    {
        return new Comparator<Card>()
            {
                @Override
                public int compare(Card pCard1, Card pCard2) {
                        return pCard1.aRank.compareTo(pCard2.aRank);
            }
        };
    }
}
```

Summary so far

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