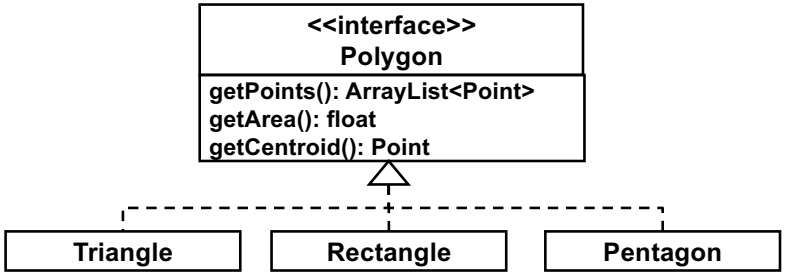
Strategy Design Pattern

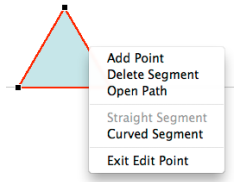
Strategy Design Pattern

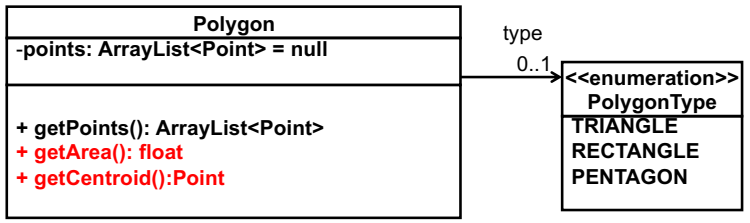
- Intent
  - Define a family of algorithms
  - Encapsulate each algorithm in a class
  - Make them interchangeable
- a.k.a
  - Policy

Recap



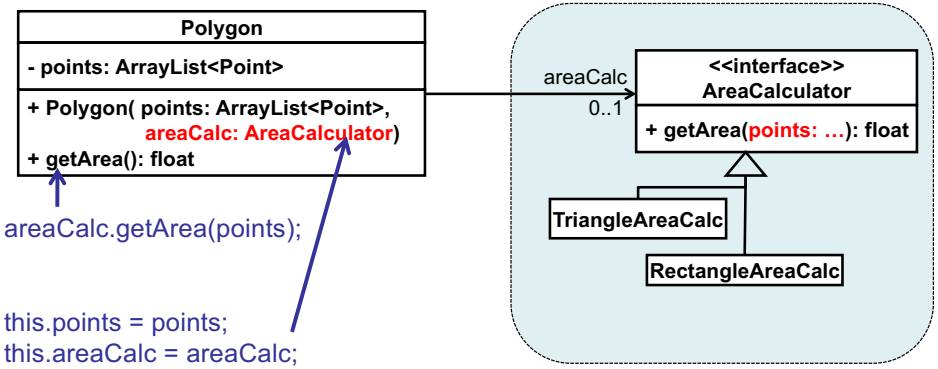
- Can a triangle become a rectangle dynamically?
- If we allow that, eliminate class inheritances





- Need to expect a conditional block, potentially a long and complicated one.

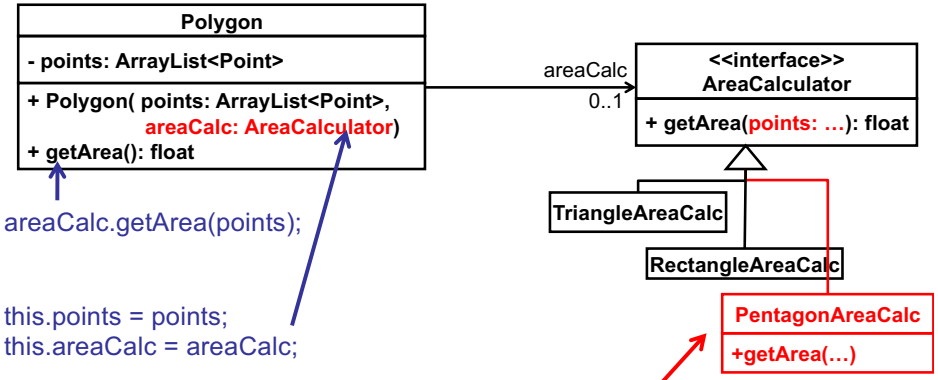
An Example of *Strategy*



Strategy Pattern:
Area calculation is "strategized."

User/client of Polygon:

```
ArrayList<Point> al = new ArrayList<Point>();
al.add( new Point(…) ); al.add( new Point(…) ); al.add( new Point(…) );
Polygon p = new Polygon( al, new TriangleAreaCalc () );
p.getArea();
```

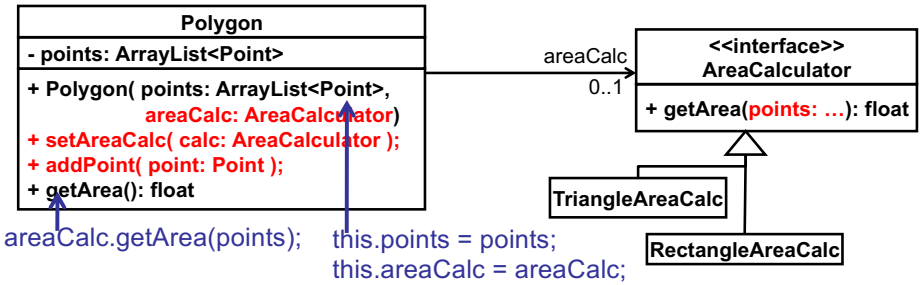



A new area calculator NEVER alter existing code (i.e., Polygon, area calcurators, and clients of Polygon).

User/client of Polygon:

```
ArrayList<Point> al = new ArrayList<Point>();
al.add( new Point(…) ); al.add( new Point(…) ); ……
Polygon p = new Polygon( al, new PentagonAreaCalc () );
p.getArea();
```


Polygon Transformation

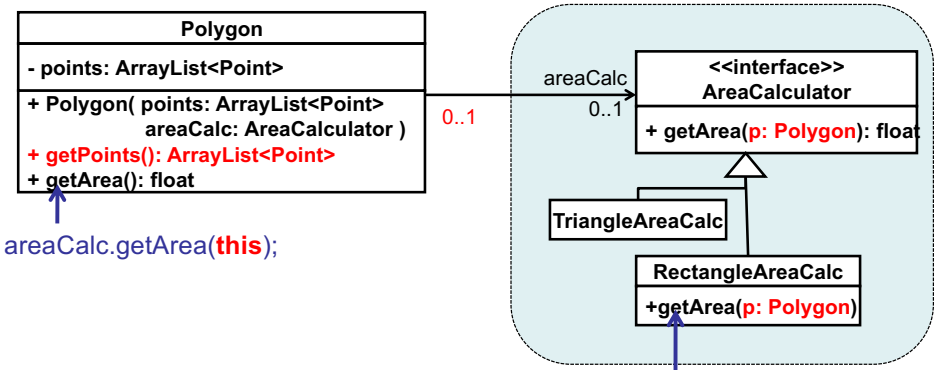


User/client of Polygon:

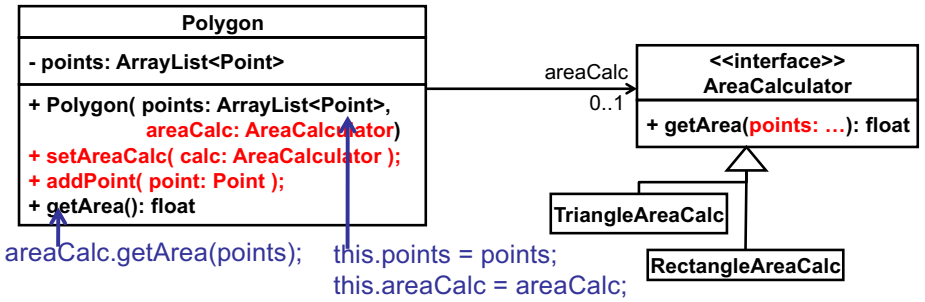
```
ArrayList<Point> al = new ArrayList<Point>();
al.add( new Point(…) ); al.add( new Point(…) ); al.add( new Point(…) );
Polygon p = new Polygon( al, new TriangleAreaCalc () );
p.getArea(); // triangle's area
p.addPoint( new Point(…) );
p.setAreaCalc( new RectangleAreaCalc () );
p.getArea(); // rectangle's area
```

No changes in existing code. Dynamic polygon transformation. Dynamic replacement of area calculators

An Alternative



HW8: Implement this

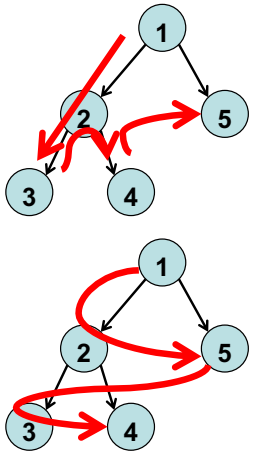


User/client of Polygon:

```
ArrayList<Point> al = new ArrayList<Point>();
al.add( new Point(…) ); al.add( new Point(…) ); al.add( new Point(…) );
Polygon p = new Polygon( al, new TriangleAreaCalc() );
p.getArea(); // triangle's area
p.addPoint( new Point(…) );
p.setAreaCalc( new RectangleAreaCalc() );
p.getArea(); // rectangle's area
```

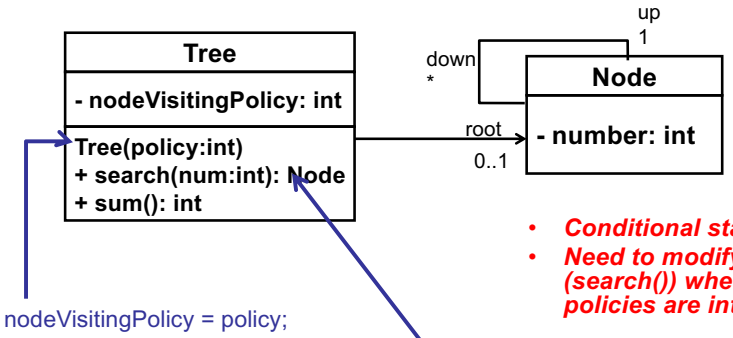

- Extend your previous HW solution/program.
  - [optional] getCentroid(), CentroidCalculator
- Dynamically transform a triangle to a rectangle, and vice vesa.

Tree Traversal with *Strategy*



- Tree traversal
  - Visiting all nodes in a tree one by one
  - Many applications:
    - AI engine for strategy games (e.g. chess)
    - Maze solving
- Two major (well-known) algorithms
  - Depth-first
  - Width-first
- Assume you need to dynamically change one traversal algorithm to another.

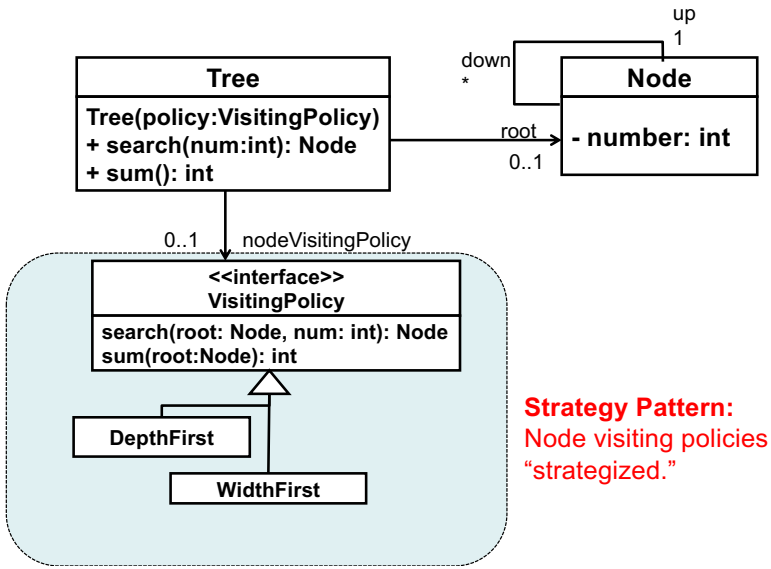
Not Good



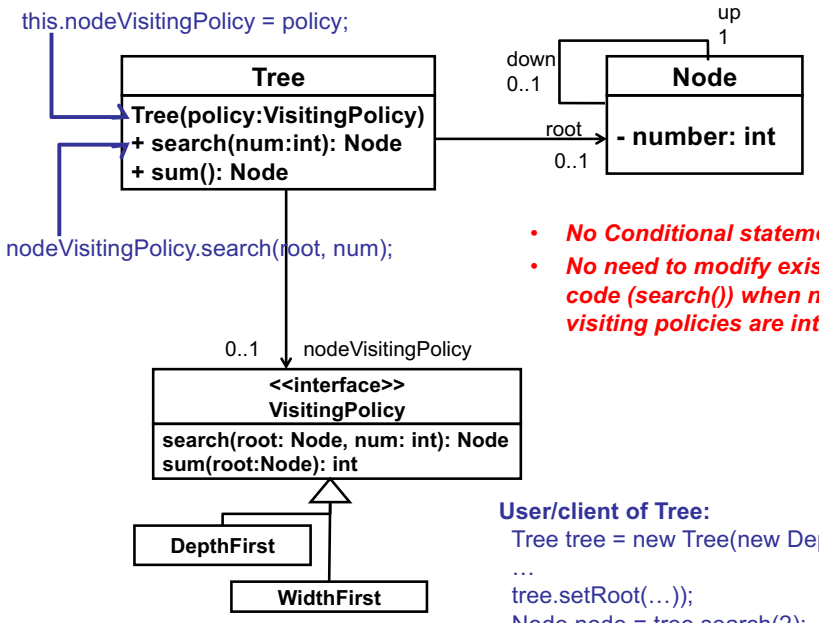
- ***Conditional statements***
- ***Need to modify existing code (search()) when new visiting policies are introduced.***

```
if(nodeVisitingPolicy==1){
  // do depth-first search
}
else if(nodeVisitingPolicy==0){
  // do width-first search
}
```

With Strategy Classes…



Strategy Pattern:
Node visiting policies are "strategized."



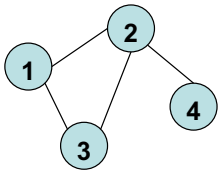
- ***No Conditional statements***
- ***No need to modify existing code (search()) when new visiting policies are introduced.***

User/client of Tree:

```
Tree tree = new Tree(new DepthFirst());
…
tree.setRoot(…));
Node node = tree.search(2);
```


Graph Traversal with *Strategy*

- A graph consists of nodes and links.
- Requirement: Find the shortest path between given two nodes.
  - 1 -> 2 -> 4: 2 hops between Node 1 and Node 4
  - 2 -> 3: 1 hop between Node 2 and Node 3

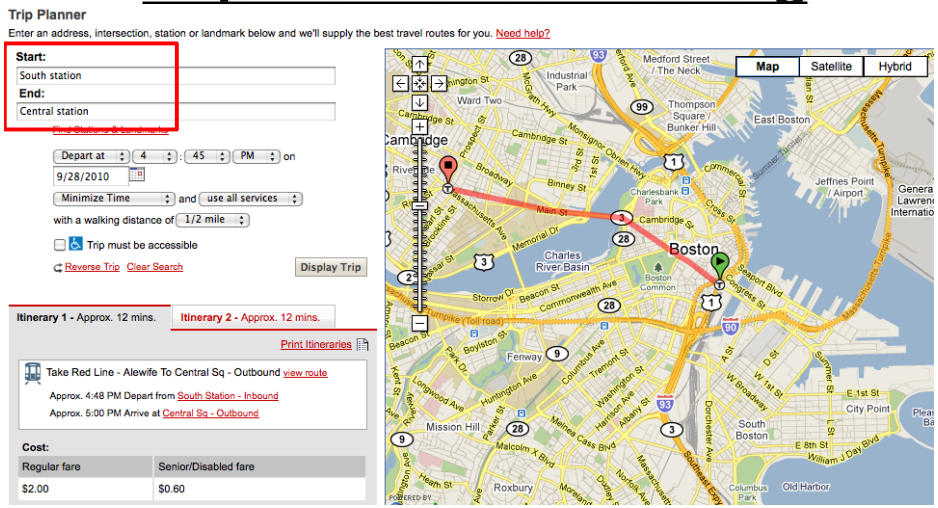


Graph
- graph: ArrayList<ArrayList<Boolean>>
+ Tree(graph:ArrayList<ArrayList<Boolean>>) + getShortestPath(n1:int, n2:int): ArrayList<Integer>

- 1 1 1 0
  1 1 1 1
  1 1 1 0
  0 1 0 1

  Connectivity matrix

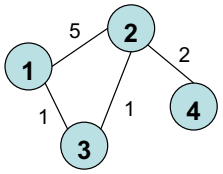
Trip Planner at mbta.org



- Directions from one place to another via T (e.g. South Station to Central Sq.)
- This is a shortest path search problem.

Weighted Graphs

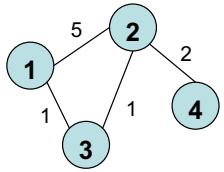
- What if you need to consider the *weighed* shortest path between two nodes?
  - 1 -> 3-> 2-> 4: total weight = 4, between Node 1 and Node 4
  - 1 -> 3 -> 2: total weight = 2, between Node 1 and Node 2



Graph
- graph: ArrayList<ArrayList<Integer>>
Tree(graph:ArrayList<ArrayList<Integer>>) + getShortestPath(n1:int, n2:int): ArrayList<Integer>

- 0 5 1 -1
5 0 1 2
1 1 0 -1
-1 2 -1 0

Weighted connectivity matrix



Graph
- graph: ArrayList<ArrayList<Boolean>>
Tree(graph:ArrayList<ArrayList<Boolean>>) + getShortestPath(n1:int, n2:int): ArrayList<Integer>

- ***Add conditional statements in getShortestPath()***
  - ***Conditional statements***
  - ***Need to modify existing code when new algorithms are introduced to compute the shortest path.***
- ***Add getWeightedShortestPath(…)***
  - ***No conditional statements***
  - ***Still need to modify existing code when new algorithms are introduced to compute the shortest path.***

Graph
- graph: ArrayList<ArrayList<Integer>>
Tree(graph:ArrayList<ArrayList<Integer>>) + getShortestPath(n1:int, n2:int): ArrayList<Integer>

graph 1

0..1 shortestPathFinder

<<interface>> ShortestPathFinder
getShortestPath(graph:Graph, n1:int, n2:int): ArrayList<Integer>

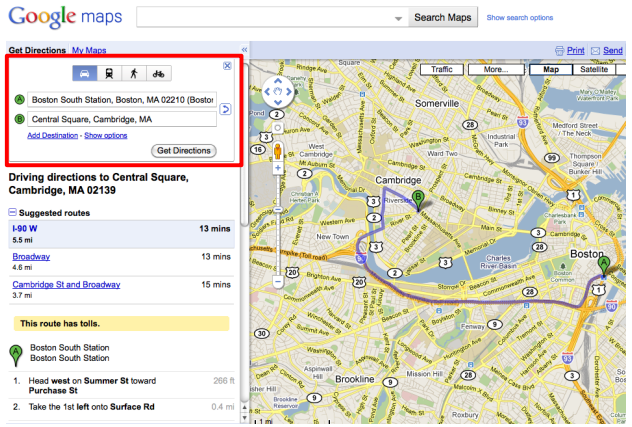
UnweigedShortestPathFinder

WeightedShortestPathFinder

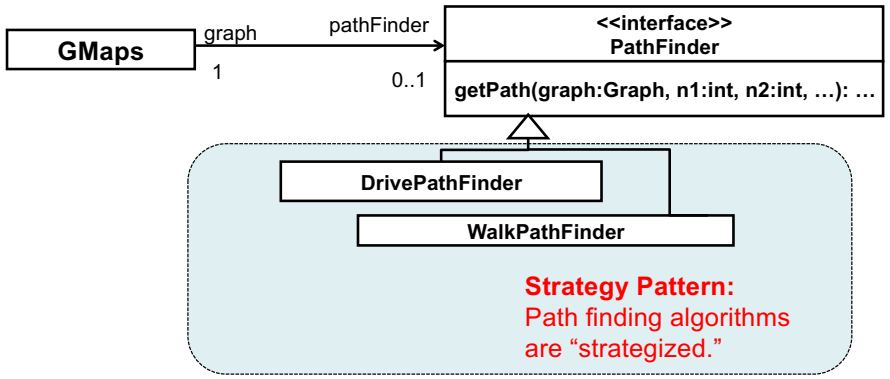
Strategy Pattern:
Shortest path algorithms are "strategized."

- ***No Conditional statements***
- ***No need to modify existing code when new algorithms are introduced.***
  - **Dijkstra's (w>=0)**
  - **Bellman-Ford**
  - **Directed graphs**

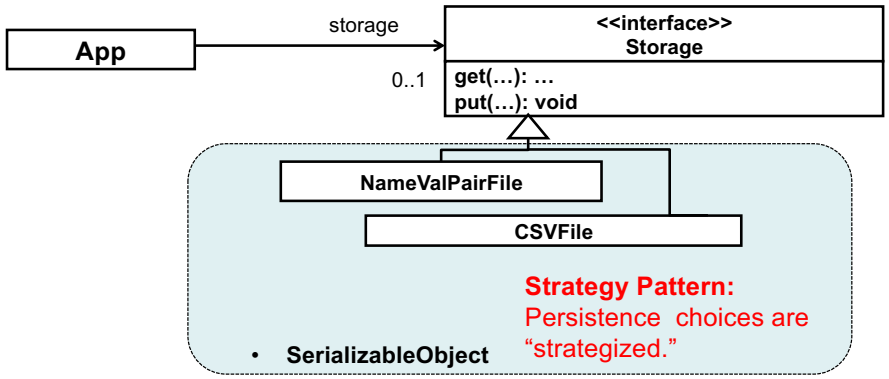
Google Maps



- Directions from one place to another (e.g. South Station to Central Sq.)
  - By car
  - By T
  - By walk
  - By bicycle
  - … extra transportation means in the future? With Uber and Lyft.



Data Storage (Persistence)



- **SerializableObject**
- **XML file**
- **YAML file**
- **JASON**

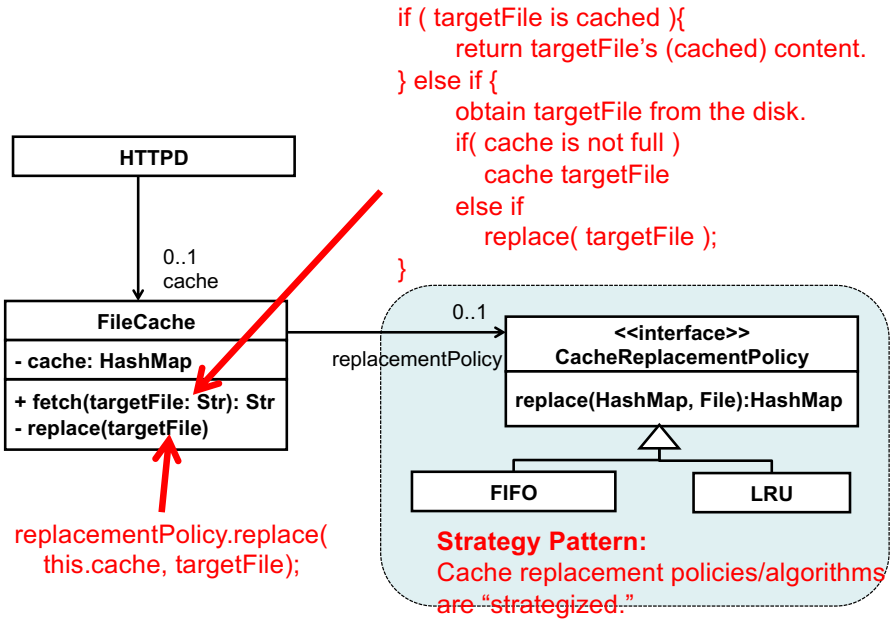
Object Pooling

- *Strategy* can be applied well to design various object pooling mechanisms.
  - Caching
  - Thread pooling
  - DB connection pooling
  - Network connection pooling
- c.f. a lecture note on *Factory Method*

Web Page Caching

- A web server
  - Receives a connection establishment request from a client (browser).
  - Receives an HTTP command
  - Retrieves a target HTML file from the local disk and returns it to the client.
  - May cache a set of HTML files that have been accessed in the past.
    - Keep them in the memory
    - Faster response to the clients
      - Memory access is much faster than disk access.

- However, the cache size is limited
  - Memory size is limited.
  - Need to determine which files to keep cached and which ones to be removed
    - When the size of cached files reaches the maximum cache size.
- Different cache replacement policies/algorithms
  - FIFO (First In First Out)
  - LRU (Least Recently Used)
  - LFU (Least Frequently Used)
  - … etc.



Comparators

- Sorting array elements:

```
int years[] = {2010, 2000, 1997, 2006};
Arrays.sort(years);
for(int y: years)
    System.out.println(y);
```

  - java.util.Arrays: a utility class (a collection of static methods) to process arrays and array elements
  - sort() sorts array elements in an ascending order.
    - 1997 -> 2000 -> 2006 -> 2010

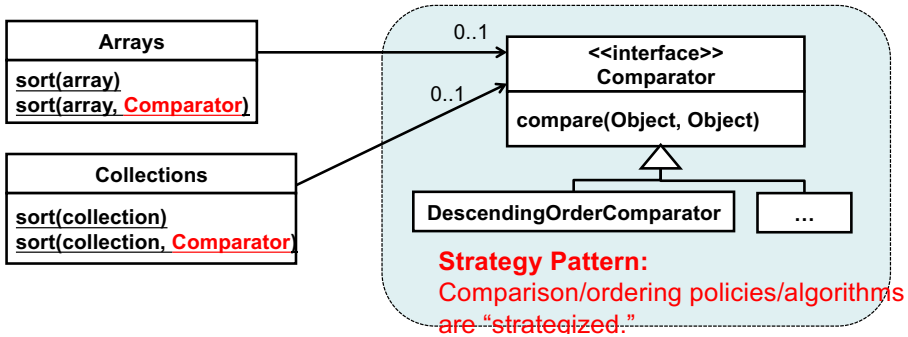
- Sorting collection elements:

```
ArrayList<Integer> years2 = new ArrayList<Integer>();
years2.add(new Integer(2010));
years2.add(new Integer(2000));
years2.add(new Integer(1997));
years2.add(new Integer(2006));
Collections.sort(years2);
for(Integer y: years2)
    System.out.println(y);
```

  - java.util.Collections: a utility class (a collection of static methods) to process collections and collection elements
  - sort() sorts array elements in an ascending order.
    - 1997 -> 2000 -> 2006 -> 2010

Comparison/Ordering Policies

- What if you want to sort array/collection elements in a descending order or any specialized (user-defined) order?
  - Arrays.sort() and Collections.sort() implement ascending ordering only.
    - They do not implement any other policies.
- Define a custom comparator by implementing java.util.Comparator



- Arrays.sort() and Collections.sort() are defined to sort array/collection elements from "smaller" to "bigger" elements.
  - By default, "smaller" elements mean the elements that have *lower* numbers.
- A descending ordering can be implemented by treating "smaller" elements as the elements that have *higher* numbers.
- compare() in comparator classes can define (or re-define) what "small" means and what's "big" means.
  - Returns a negative integer, zero, or a positive integer as the first argument is "smaller" than, "equal to," or "bigger" than the second.

```
• public class DescendingOrderComparator implements Comparator{
    public int compare(Object o1, Object o2){
      return ((Integer)o2).intValue()-((Integer) o1).intValue();
    }
  }
```


Sorting Collection Elements with a Custom Comparator

```
– ArrayList<Integer> years = new ArrayList<Integer>();
  years.add(new Integer(2010)); years.add(new Integer(2000));
  years.add(new Integer(1997)); years.add(new Integer(2006));
  Collections.sort(years);
  for(Integer y: years)
      System.out.println(y);
  Collections.sort(years, new DescendingOrderComparator());
  for(Integer y: years)
      System.out.println(y);
```

– 1997 -> 2000 -> 2006 -> 2010

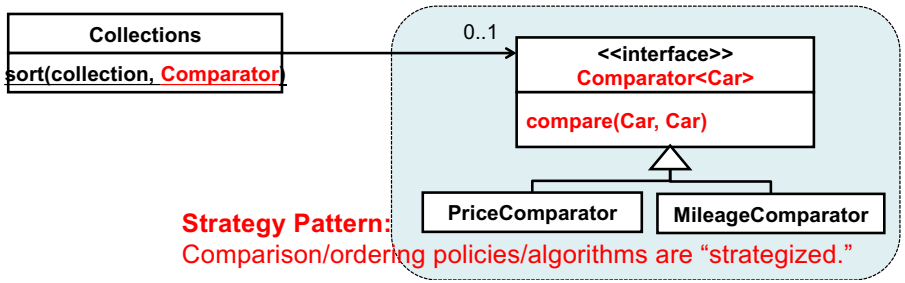
– 2010 -> 2006 -> 2000 -> 1997


```
• public class DescendingOrderComparator implements Comparator{
    public int compare(Object o1, Object o2){
      return ((Integer)o2).intValue()-((Integer) o1).intValue();
    }
  }
```

- A more type-safe option is available/recommended:

```
• public class DescendingOrderComparator<Integer>{
    implements Comparator<Integer>{
      public int compare(Integer o1, Integer o2){
        return o2.intValue()-o1.intValue();
      }
  }
```

- What if you want to sort a collection of your own (i.e., user-defined) objects?
  - ```
    class Car{
      private int getPrice();
      private int getYear();
      private float getMileage();
    }
    ```
  - ```
    ArrayList<Car> usedCars= new ArrayList<Car>();
    usedCars.add(new Car(…)); usedCars.add(…); usedCars.add(…);
    Collections.sort(usedCars);
    ```
- Need to define a car-ordering policy as a custom comparator class.



Strategy Pattern:
Comparison/ordering policies/algorithms are "strategized."

- Assume "bigger" (or better) elements as the elements that have a
  - Lower price
  - Higher (more recent) year
  - Lower mileage

- ```
  public class PriceComparator<Car>
    implements Comparator<Car>{
      public int compare(Car car1, Car car2){
        return car2.getPrice() - car1.getPrice();
      }
  }
  ```
- ```
  public class YearComparator<Car>
    implements Comparator<Car>{
      public int compare(Car car1, Car car2){
        return car1.getYear() - car2.getYear();
      }
  }
  ```


Thanks to *Strategy*…

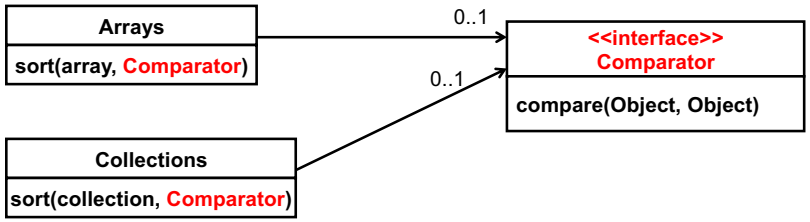
- You can define any extra ordering/comparison policies without changing existing code
  - e.g., Car, Collections.sort()
  - No conditional statements to shift ordering/comparison policies.

- You can dynamically change one ordering/comparison policy to another.
  - ```
    Collections.sort(usedCars, new PriceComparator());
    // printing a list of cars
    Collection.sort(usedCars, new YearComparator());
    // printing a list of cars
    ```

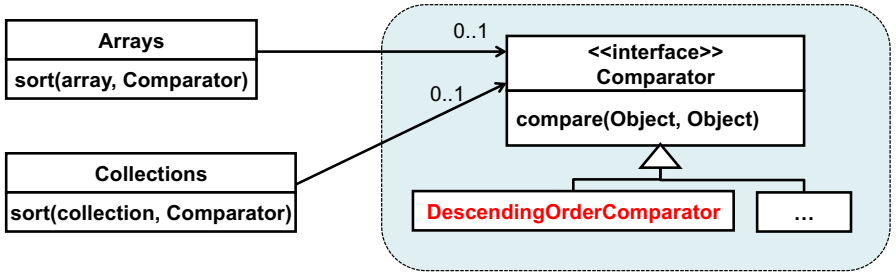

Used Car Listings

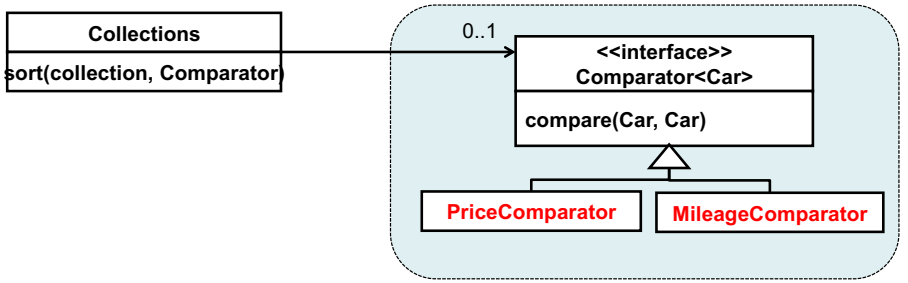

    ```

Programming to an Interface

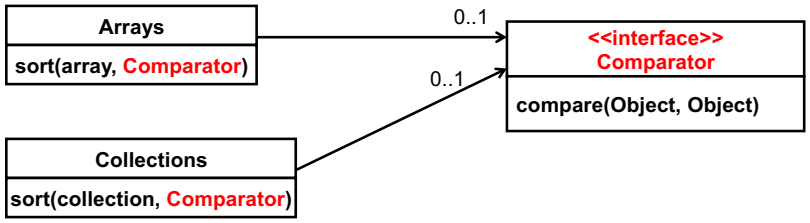


- One of the most important points in *Strategy*
- What Java API designers did was to…
  - Define the interface Comparator only.
    - Users of Arrays/Collections will define their comparator implementations.





Programming to an Interface



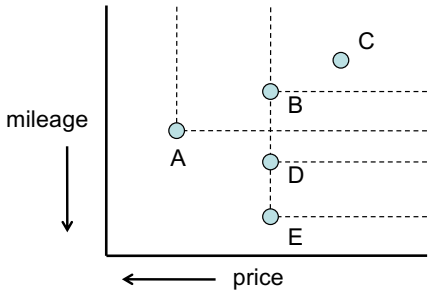
- What Java API designers intended was to…
  - make Arrays.sort() and Collections.sort() intact even if changes occur in Comparator implementations
  - make Arrays and Collections loosely-coupled from Comparator implementations.

HW 9

- Implement the Car class and three comparator classes
  - [Optional] Implement an extra comparator, `ParetoComparator<Car>`, which performs the *Pareto comparison*.
- Test cases make several cars and sort them with three (or four) comparators.

Pareto Comparison

- Given multiple objectives,
  - e.g., price, year and mileage
- Car A is said to ***dominate*** (or outperform) Car B iif:
  - A's objective values are superior than, or equal to, B's in all objectives, and
  - A's objective values are superior than B's in at least one objective.



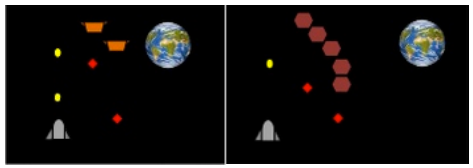
  - Count the number of cars that dominate a car in question
    - A: 0
    - B: 3 (A, D, E)
    - C: 4 (A, B, D, E)
    - D: 1 (E)
    - E: 0
  - Better cars have lower "domination counts."

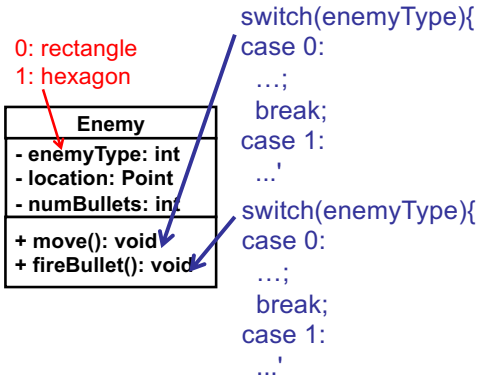
- Implement getDominationCount() in Car.
- When to compute domination counts for individual cars?
  - Before calling sort()
    - `// finish up computing domination counts for all cars.`
      `Collections.sort(usedCars, new PriceComparator<Car>());`
  - When calling sort()
    - `Collections.sort(usedCars,`
      `new PriceComparator<Car>(usedCars));`

Optional HW

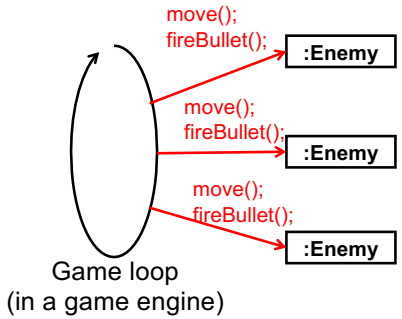
- Replace Type Code with Class (incl. enumeration)
  - http://sourcemaking.com/refactoring/replace-type-code-with-class
- Replace Type Code with State/Strategy
  - http://sourcemaking.com/refactoring/replace-type-code-with-state-strategy
- Replace Type Code with Subclasses
  - http://sourcemaking.com/refactoring/replace-type-code-with-subclasses
- Replace Conditional with Polymorphism
  - http://sourcemaking.com/refactoring/replace-conditional-with-polymorphism

One More Exercise
Imagine a Simple 2D Shooting Game



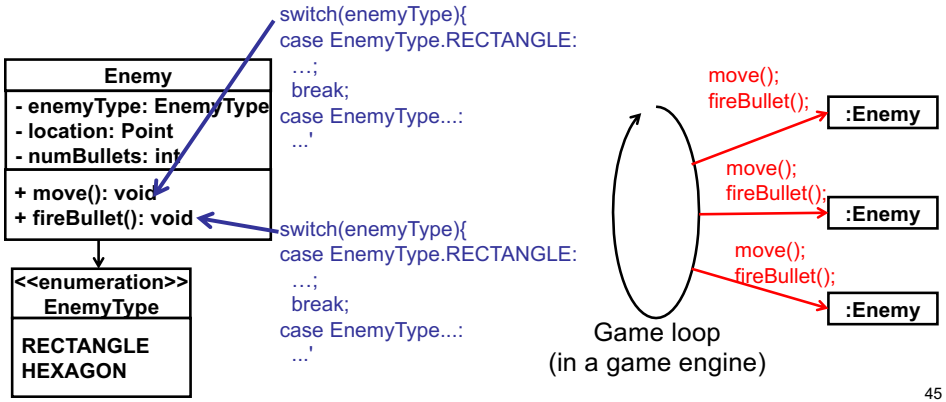


- Each type of enemies has its own attack pattern.
  - e.g. How to move, when to fire bullets, how to fire bullets…



What's Bad?

- Using magic numbers.
  - Replace them with symbolic constants or an enumeration.
    - c.f. Lecture note #3

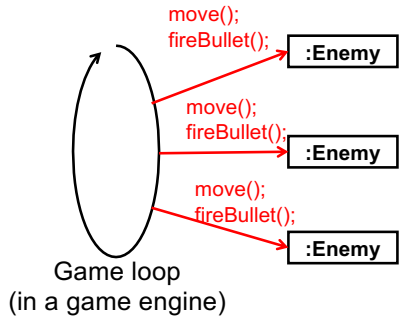


Still Not Good

- Conditional blocks. Error-prone to maintain them
  - If there are many enemy types.
  - If new enemy types may be added in the near future.
    - Imagine 3,000 or 5,000 lines of code for each conditional block
  - If repetitive conditional blocks exist.
- Attack patterns (moving patterns and firing patterns) are tightly coupled with Enemy. Hard to maintain them
  - If attack patterns often change.
    - Revising hexagonal enemy's moving pattern
    - Having the same moving pattern for rectangle and hexagonal enemies.
    - Changing rectangle enemy's moving pattern to be more intelligent as you play
    - Introducing a new type of enemies and having them use hexagonal enemy's moving pattern
    - Introducing a new type of enemies and implementing a new pattern for them.

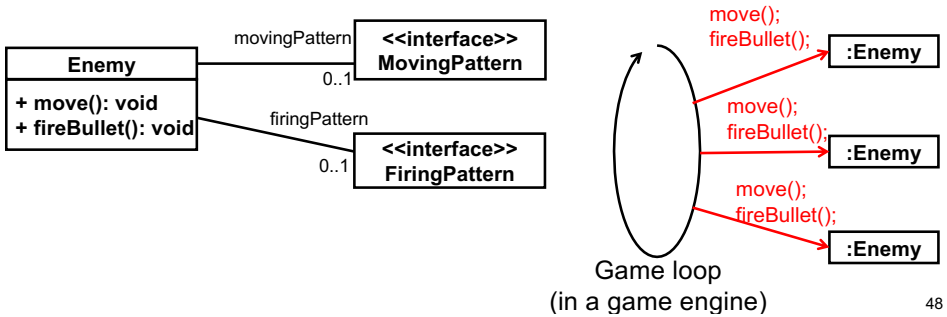
What We Want are to…

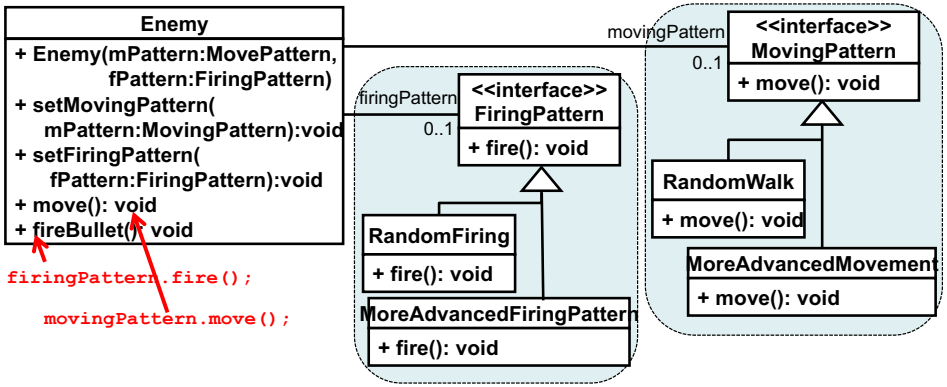
- Eliminate those conditional blocks.
- Separate Enemy and its attack patterns (moving patterns and firing patterns).
  - Make Enemy and its attack patterns loosely coupled.
- Define a family of attack patterns (algorithms) in a unified way
- Encapsulate each algorithm in a class
- Make algorithms interchangeable



Complete the Design with *Strategy*

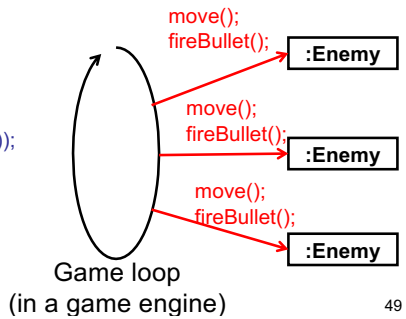
- Complete the class diagram with *Strategy*
  - Add classes, methods and data fields as you like.
- Show how Enemy's move() and fireBullet() look like.





User/client of Enemy:

```
Enemy e1 = new Enemy(new RandomWalk(…),
                     new RandomFiring(…));
Enemy e2 = new Enemy(new RandomWalk(…),
                     new MoreAdvancedPattern(…));
Enemy e3 = …
ArrayList<Enemey> el = new ArrayList<Enemy>();
el.add(e1); el.add(e2); el.add(e3);
for(Enemy e: el){
   e.move();
   e.fireBullet(); }
```



Game loop
(in a game engine)