

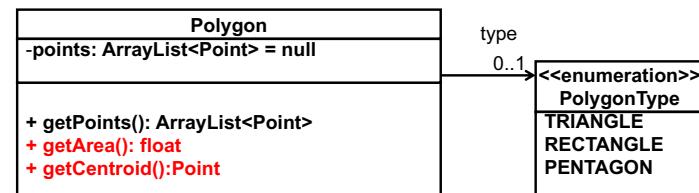
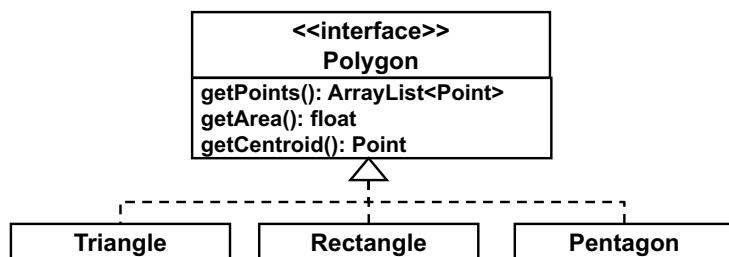
Strategy Design Pattern

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

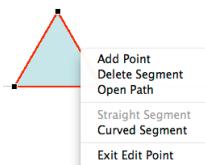
2

Strategy Design Pattern

Recap



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

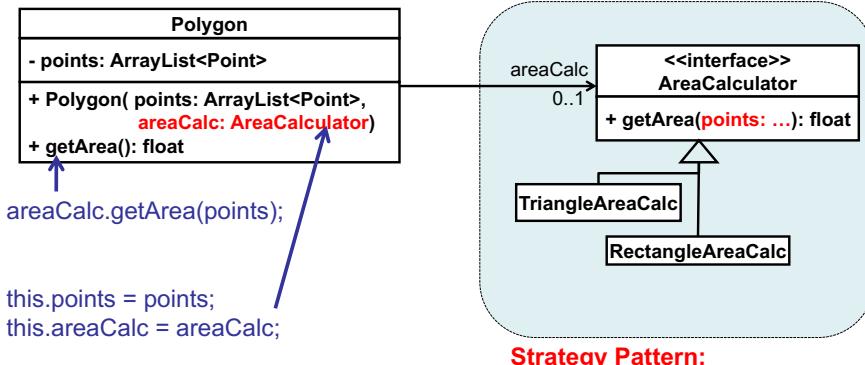


3

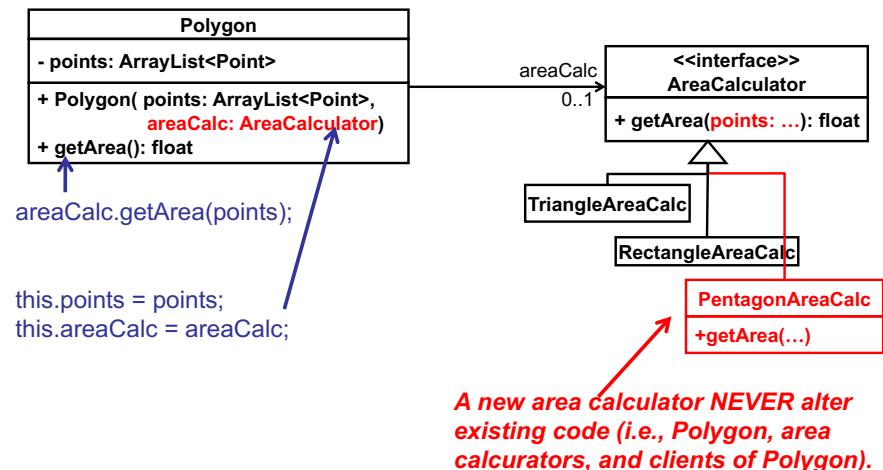
- Need to expect a conditional block, potentially a long and complicated one.

4

An Example of Strategy

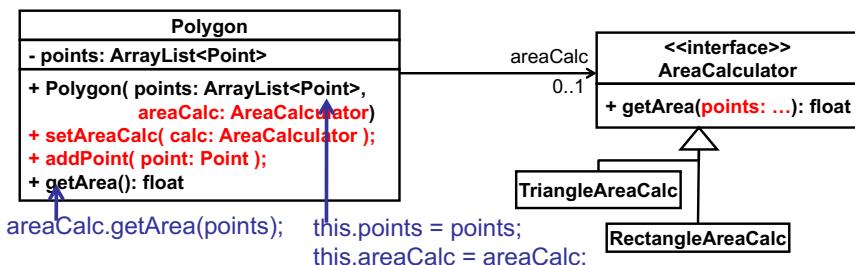


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6

Polygon Transformation



7

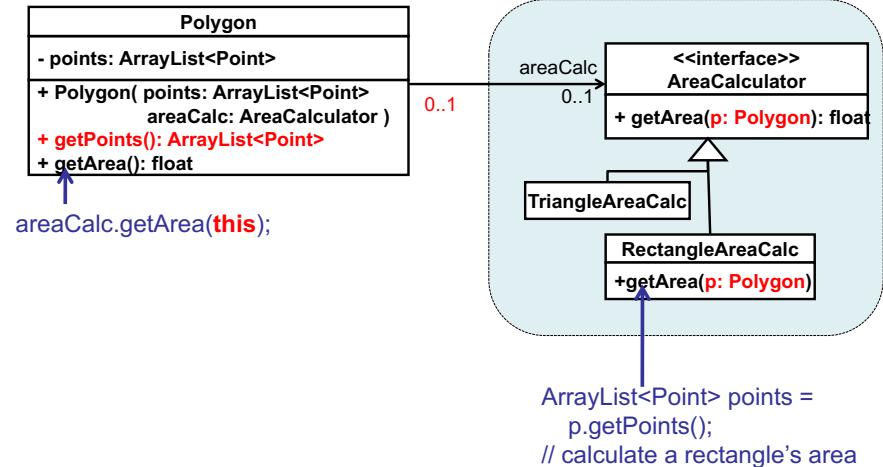
No changes in existing code. Dynamic polygon transformation.
Dynamic replacement of area calculators

User/client of Polygon:

```

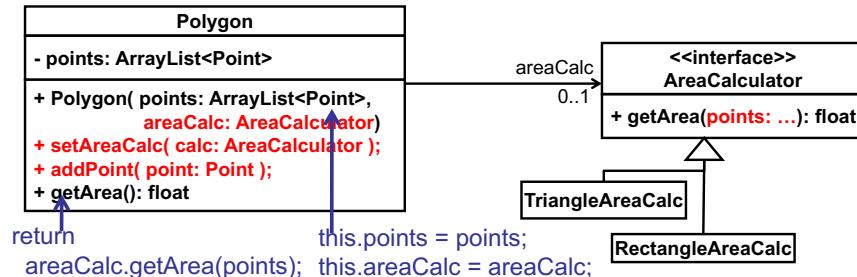
ArrayList<Point> al = new ArrayList<Point>();
al.add( new Point(...) ); al.add( new Point(...) ); .....
Polygon p = new Polygon( al, new PentagonAreaCalc() );
p.getArea();
  
```

An Alternative



8

HW 5: 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
```

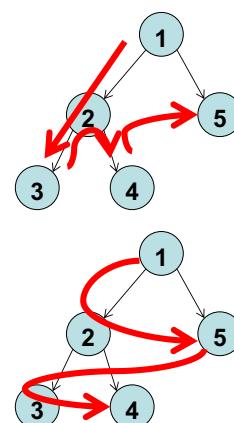
9

- Dynamically transform a triangle to a rectangle, and vice versa.
 - You can make a simple assumption about how the triangle and rectangle look like.
 - e.g. $[(0,0), (0,10), (10,0)] \rightarrow [(0,0), (0,10), (10,10), (10,0)]$
 - $[(0,0), (0,10), (10,10), (10,0)] \rightarrow [(0,0), (0,10), (10,0)]$
 - **FIRM DUE:** November 14 (Tue) midnight

- Define two classes that implements the AreaCalculator interface (Triangle and Rectangle).
 - You can reuse Point in Java API or define your own.
- Implement getPoints() and getArea() in the two subclasses.
 - Use Heron's formula to compute a triangle's area.
 - The area of a triangle = $\text{Sqrt}(s(s-a)(s-b)(s-c))$
 - where $s=(a+b+c)/2$
 - a, b and c are the lengths of the triangle's sides.
- Write test code (in main() or with JUnit) that
 - Makes two different triangles and two different rectangles,
 - Contains those 4 polygons in a collection (e.g. ArrayList),
 - Use generics and an iterator
 - Prints out each polygon's area.
 - Take advantage of polymorphism.

10

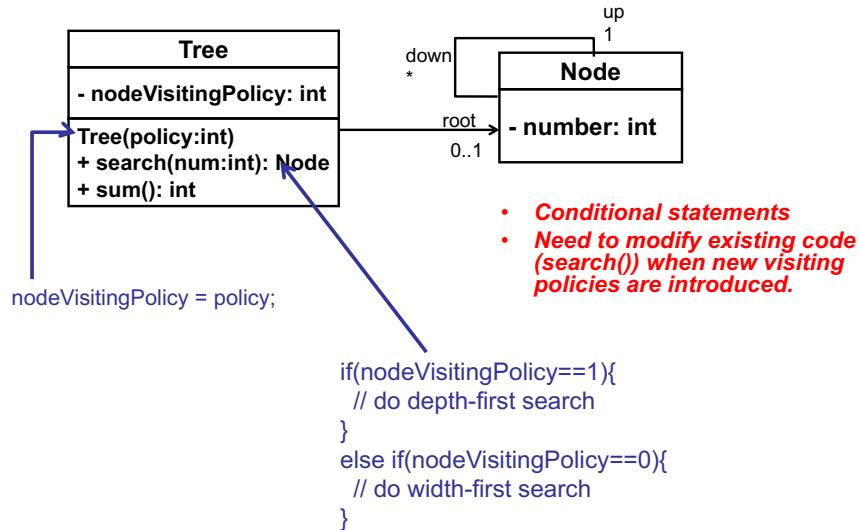
Tree Traversal with Strategy



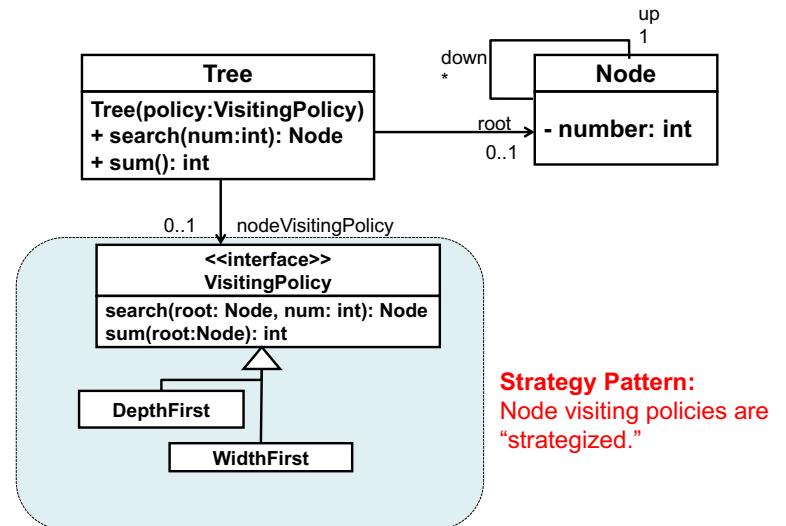
- Tree traversal
 - Visiting all nodes in a tree one by one
 - Many applications:
 - AI engine for strategy games (e.g. chess)
 - Maze solving
 - Two major (well-known) algorithms
 - Depth-first
 - Width-first
 - Assume you need to dynamically change one traversal algorithm to another.

11

Not Good

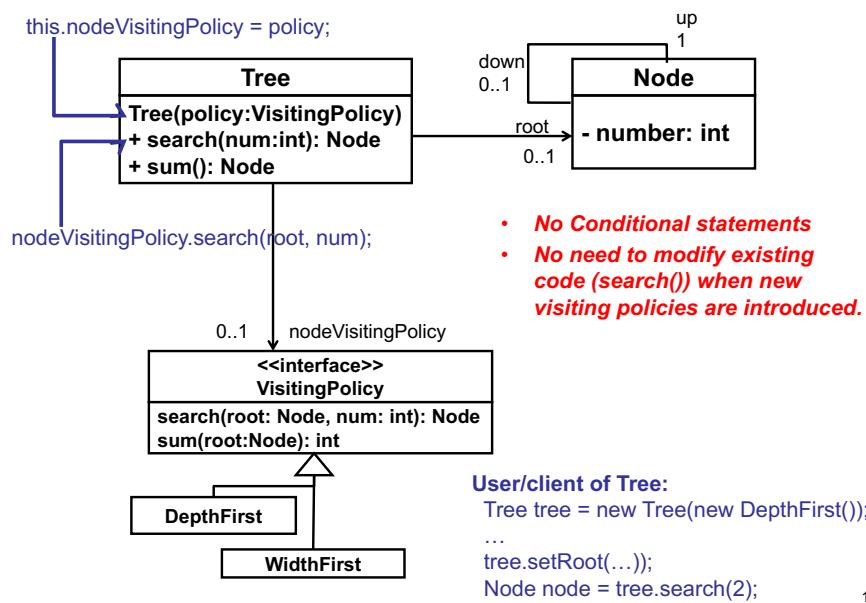


With Strategy Classes...



13

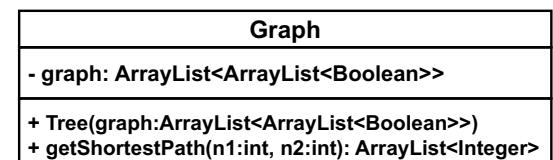
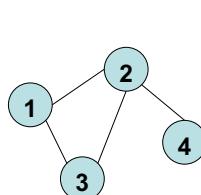
14



15

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



• 1 1 1 0
 1 1 1 1
 1 1 1 0
 0 1 0 1

Connectivity matrix

16

Trip Planner at mbta.org

Trip Planner
Enter an address, intersection, station or landmark below and we'll supply the best travel routes for you. [Need help?](#)

Start: South station
End: Central station

Depart at: 4:45 PM on 9/28/2010
Minimize Time and use all services
with a walking distance of 1/2 mile
Trip must be accessible
Reverse Trip Clear Search Display Trip

Itinerary 1 - Approx. 12 mins. Itinerary 2 - Approx. 12 mins.
Print Itineraries Take Red Line - Alewife To Central Sq - Outbound [view route](#).
Approx. 4:48 PM Depart from South Station - Inbound
Approx. 5:00 PM Arrive at Central Sq - Outbound

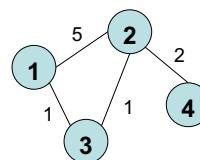
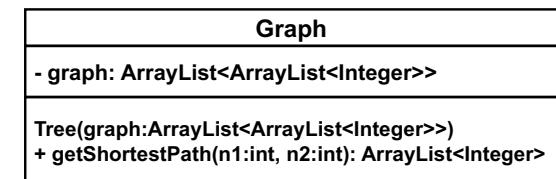
Cost:
Regular fare Senior/Disabled fare
\$2.00 \$0.60

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

17

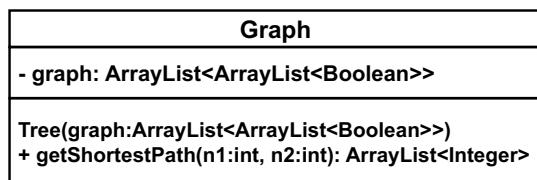
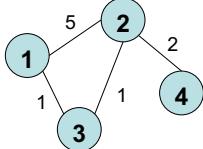
Weighted Graphs

- What if you need to consider the *weighted* 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



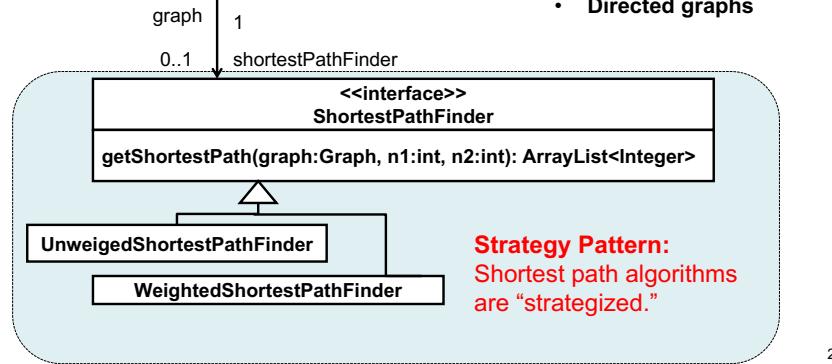
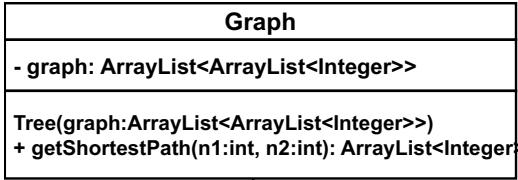
- 0 5 1 -1
5 0 1 2
1 1 0 -1
-1 2 -1 0
- Weighted connectivity matrix

18



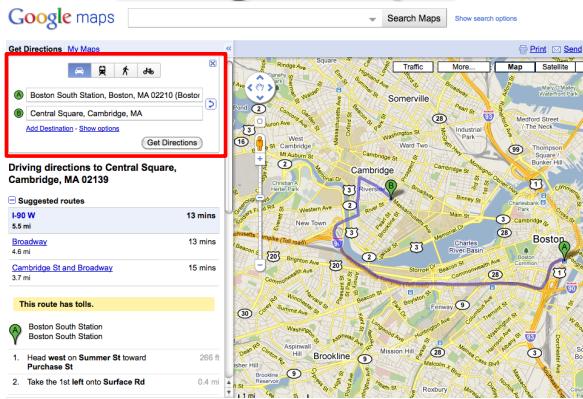
- Add conditional statements in `getShortestPath()`
 - Conditional statements
 - Need to modify existing code when new algorithms are introduced to compute the shortest path.
- Add `getWeightedShortestPath(...)`
 - No conditional statements
 - Still need to modify existing code when new algorithms are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

19



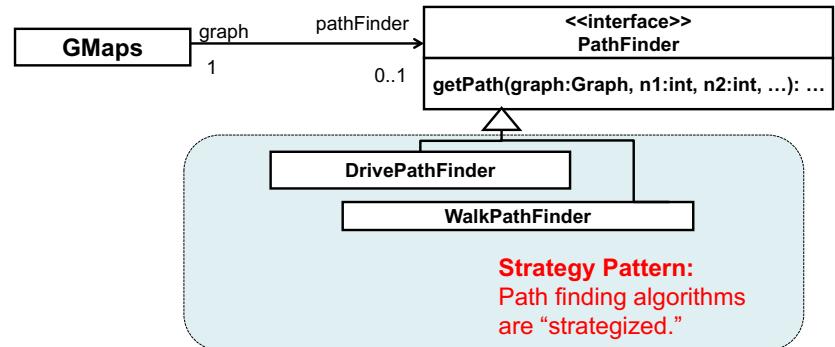
20

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.

21



22

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*

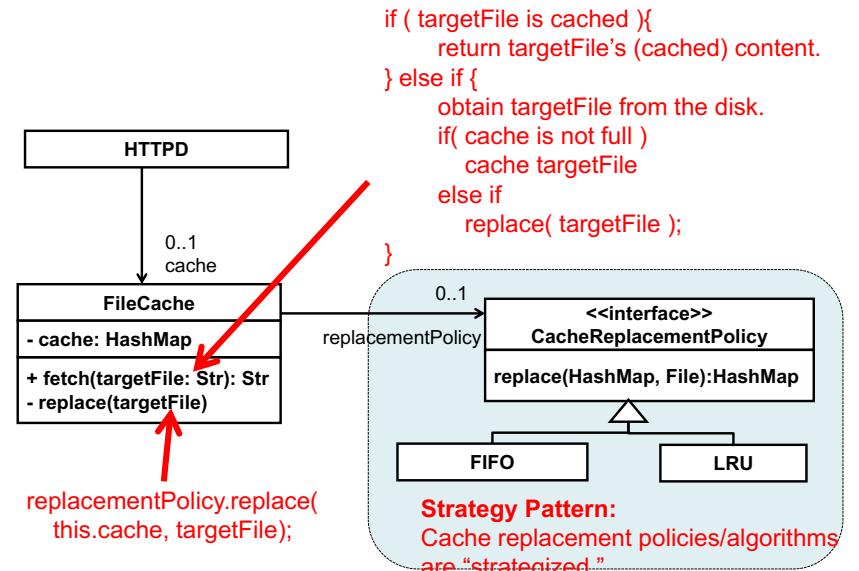
Web Page Caching

- 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.

23

- 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.

25



26

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

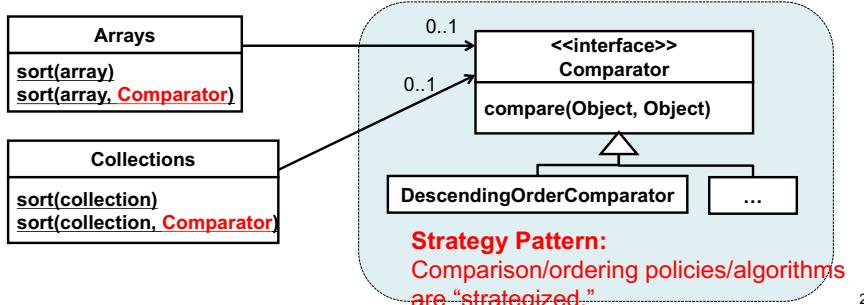
27

- 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

28

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();  
    }  
}
```

30

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();
 }
 }
}
```

31

32

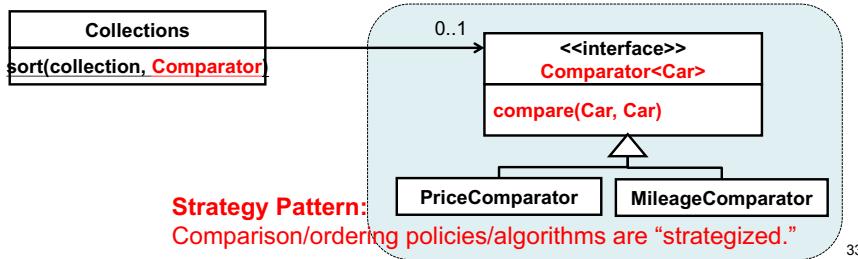
- What if you want to sort a collection of your own (i.e., user-defined) objects?

```

- class Car{
 public int getPrice();
 public int getYear();
 public 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.



33

- 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();
 }
}

```

34

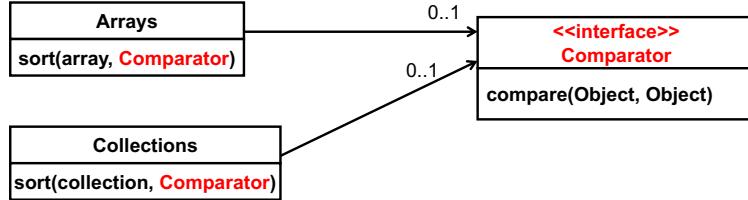
## Thanks to Strategy...

- 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

35

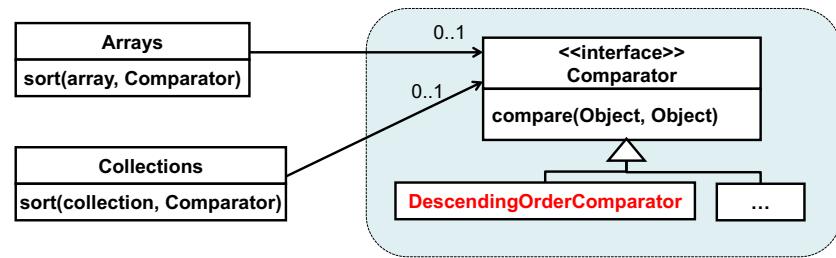
| Used Car Listings                                |                                                           |         |                                                                                       |          |                                                                                                                                 |
|--------------------------------------------------|-----------------------------------------------------------|---------|---------------------------------------------------------------------------------------|----------|---------------------------------------------------------------------------------------------------------------------------------|
| Year/Model                                       | Information                                               | Mileage | Seller/Distance                                                                       | Price    |                                                                                                                                 |
| 2000 Audi A4 5dr Wgn 1.8T Avant Auto Quattro AWD | Used<br>MPG: 19 City / 28 Hwy<br>Automatic Gray           | 136,633 | Dedham Auto Mall<br>(7.4 Miles)<br>Search Dealer Inventory                            | \$4,880  |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2001 Audi A4                                     | Used                                                      | 84,297  | Herb Connolly Hyundai<br>(16.8 Miles)<br>Search Dealer Inventory                      | \$7,995  |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2002 Audi A6 4dr Sdn quattro AWD Auto            | Used<br>MPG: 17 City / 25 Hwy<br>Automatic Blue           | 84,272  | Dedham Auto Mall<br>(7.4 Miles)<br>Search Dealer Inventory                            | \$7,998  |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2003 Audi A4 1.8T                                | Used<br>MPG: 20 City / 28 Hwy<br>Automatic Blue           | 78,321  | Direct Auto Mall<br>(18.8 Miles)<br>Search Dealer Inventory                           | \$10,697 |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2002 Audi allroad 5dr quattro AWD Auto           | Used<br>MPG: 15 City / 21 Hwy<br>Automatic Green          | 98,382  | Lux Auto Plus<br>(8.6 Miles)<br>Search Dealer Inventory                               | \$10,900 |  <a href="#">Get a CARFAX Record Check</a> |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2008 Audi A6                                     | Certified Pre-Owned<br>MPG: 17 City / 25 Hwy<br>Automatic | 0       | Audi Burlington & Porsche<br>of Burlington<br>(14.9 Miles)<br>Search Dealer Inventory | \$37,897 |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2007 Audi A4                                     | Used<br>MPG: 22 City / NA Hwy<br>Brilliant Black          | 6,822   | (19.3 Miles)                                                                          | \$24,995 |  <a href="#">Get a CARFAX Record Check</a> |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2009 Audi A4                                     | Certified Pre-Owned<br>White                              | 10,120  | Audi Burlington & Porsche<br>of Burlington<br>(14.9 Miles)<br>Search Dealer Inventory | \$33,497 |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2009 Audi A4 3.2L Prestige                       | Certified Pre-Owned<br>Automatic White                    | 12,118  | Audi Burlington & Porsche<br>of Burlington<br>(14.9 Miles)<br>Search Dealer Inventory | \$39,877 |  <a href="#">Free CARFAX Report</a>        |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |
| 2008 Audi S5                                     | Used<br>Brilliant Black                                   | 16,492  | (18.3 Miles)                                                                          | \$44,995 |  <a href="#">Get a CARFAX Record Check</a> |
| More Photos >>                                   |                                                           |         |                                                                                       |          |                                                                                                                                 |

# Programming to an Interface

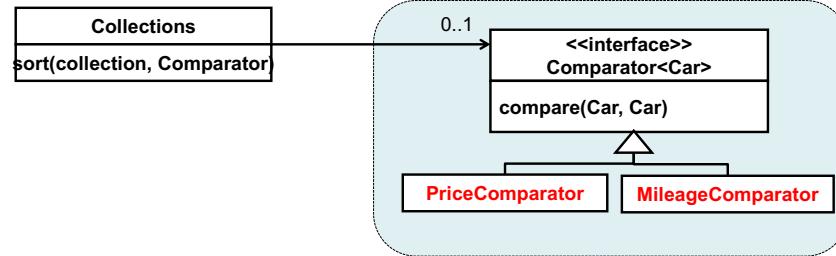


- One of the most important points in *Strategy*
- What Java API designers did was to...
  - Define the interface Comparator only.
    - Users of Arrays/Collections will define their comparator implementations.

37

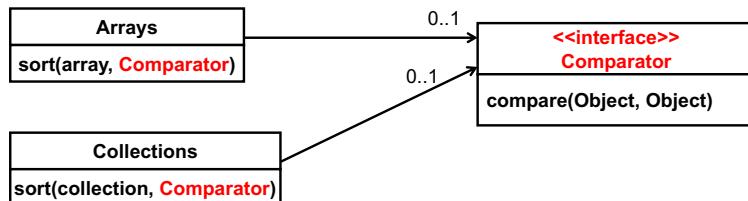


38



39

# 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.

39

## HW 6

- 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.

40

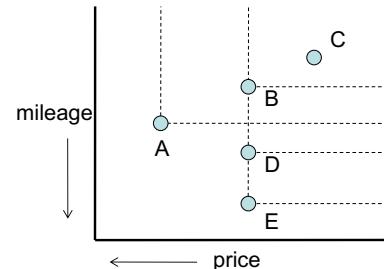
## Optional HW

- 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>

41

## Pareto Comparison

- Given multiple objectives,
  - e.g., price, year and mileage
- Car A is said to **dominate** (or outperform) Car B if:
  - 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 each car.
  - A: 0 (No cars dominate A.)
  - B: 3 (A, D, E)
  - C: 4 (A, B, D, E)
  - D: 1 (E)
  - E: 0 (No cars dominate E.)
- Better cars have lower “domination counts.”
  - To order cars from the best one(s) to the worst one(s), compare() should treat “better” ones as “smaller” ones.



42

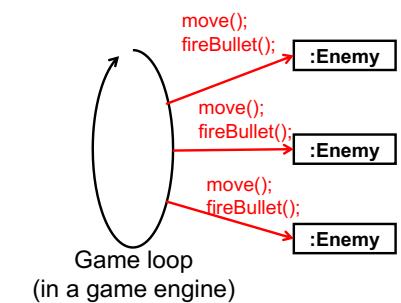
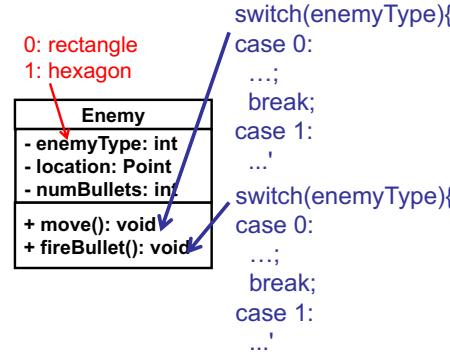
- Implement getDominationCount() in Car.
- When to compute domination counts for individual cars?
  - Before calling sort()

```
// finish up computing domination counts for all cars
// by calling getDominationCount() on those cars, and
// then call sort()
Collections.sort(usedCars, new DominationComparator<Car>());
```
  - When calling sort()

```
// DominationComparator's constructor calls
// getDominationCount() on individual cars.
Collections.sort(usedCars,
 new DominationComparator<Car>(usedCars));
```
- FIRM Due: Nov 21 (Tue) midnight

43

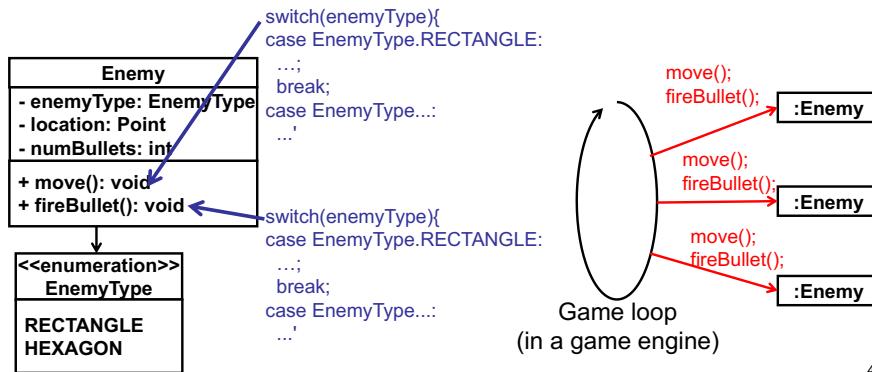
## One More Exercise Imagine a Simple 2D Shooting Game



44

## What's Bad?

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



45

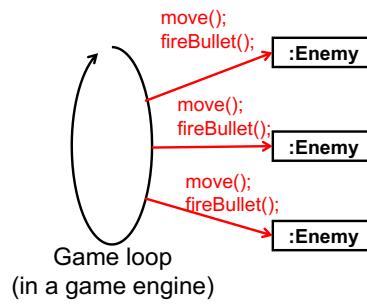
## Still Not Good

- 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.

46

## What We Want are to...

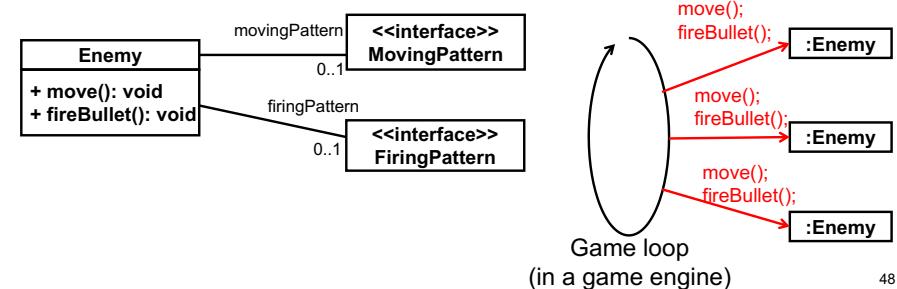
- Eliminate those conditional blocks.
- Separate `Enemy` and its attack patterns (moving patterns and firing patterns).
  - Make `Enemy` and its attack patterns loosely coupled.
- Define a family of attack patterns (algorithms) in a unified way
- Encapsulate each algorithm in a class
- Make algorithms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



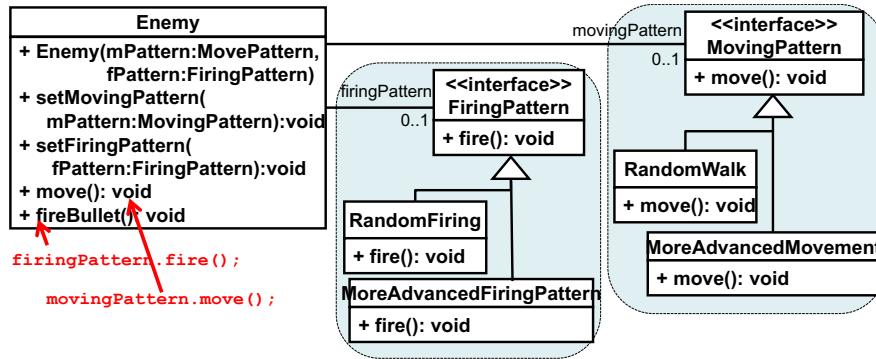
47

## 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.



48

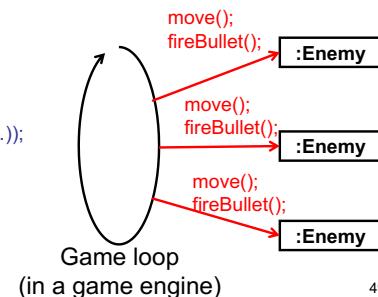


**User/client of Enemy:**

```

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

```

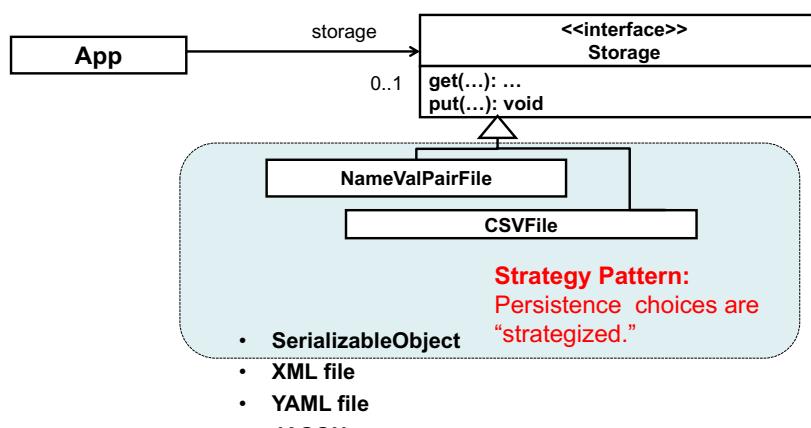


49

50

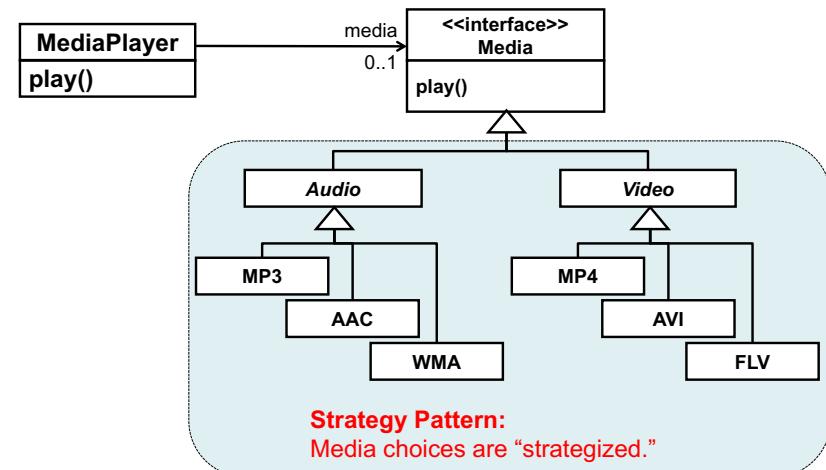
## Other Examples of Strategy

## Data Storage (Persistence)



51

## Media Player



52