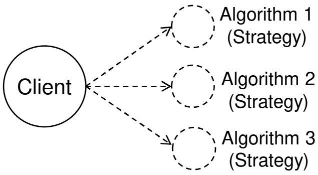
## GoF Design Patterns (contd)

## The Strategy Pattern (Behavioral)



The behavior of a class may change during the lifetime (runtime) of an object of this class.

**Example:**

Such a design problem in the example POS system is the complex pricing policy.

The pricing strategy (which may also be called a rule, policy, or algorithm) for sale can vary.

For example,

- Mondays, it may be 10%, and Thursdays, 5% off all sales (percentage)
- It may be 10TL off, if the sale total is greater than 200TL (absolute),
- For customers with a loyalty card, there may be other discounts (customer-based).

All these different algorithms (pricing strategies) seem to be variations of the getTotal() responsibility (behavior) of the Sale class.

However, adding all these algorithms into the getTotal() method of the Sale using if-then-else or switch-case statements will cause coupling and cohesion problems.

All changes in pricing strategies will affect the Sale.

**Definition:** Strategy

Problem:

How should we design for varying but related algorithms or policies?

How should we design for the ability to change these algorithms or policies?

(A certain behavior of a class may change during the lifetime of an object of this class.)

Solution:

Define each algorithm/policy/strategy in a separate class with a common interface.

**The solution to the problem with different pricing strategies:**

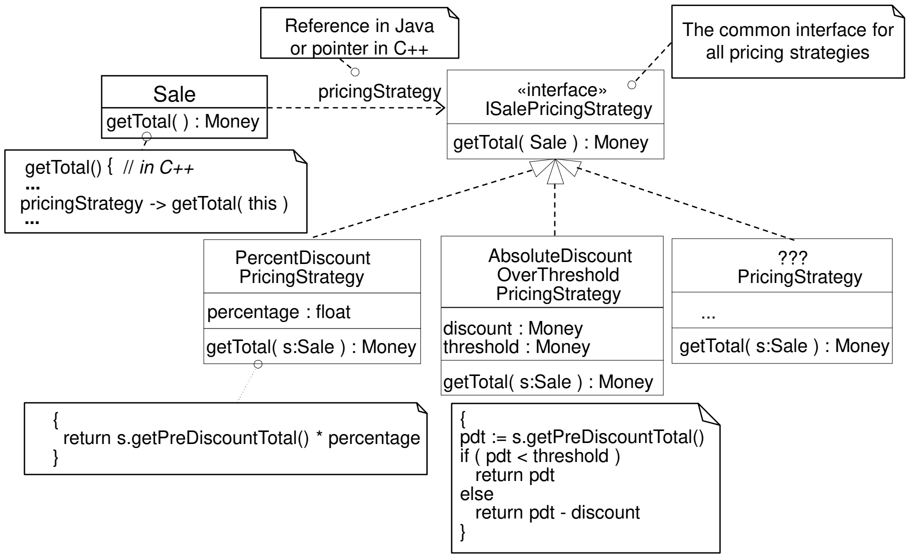
According to the strategy pattern, we create multiple SalePricingStrategy classes for different discount algorithms, each with a polymorphic getTotal method.

The implementation of each getTotal method will be different: PercentDiscountPricingStrategy will discount by a percentage, and so on.

Each getTotal method takes the Sale object as a parameter so that the pricing strategy object can get the pre-discount price from the Sale and then apply the discounting rule.

**Example** (Different Discount Policies) :

The solution to the problem of different discount policies using the Strategy.



```
getTotal() {  // in C++
...
pricingStrategy -> getTotal( this )
...
```

```
{
  return s.getPreDiscountTotal() * percentage
}
```

```
{
pdt := s.getPreDiscountTotal()
if ( pdt < threshold )
   return pdt
else
   return pdt - discount
}
```

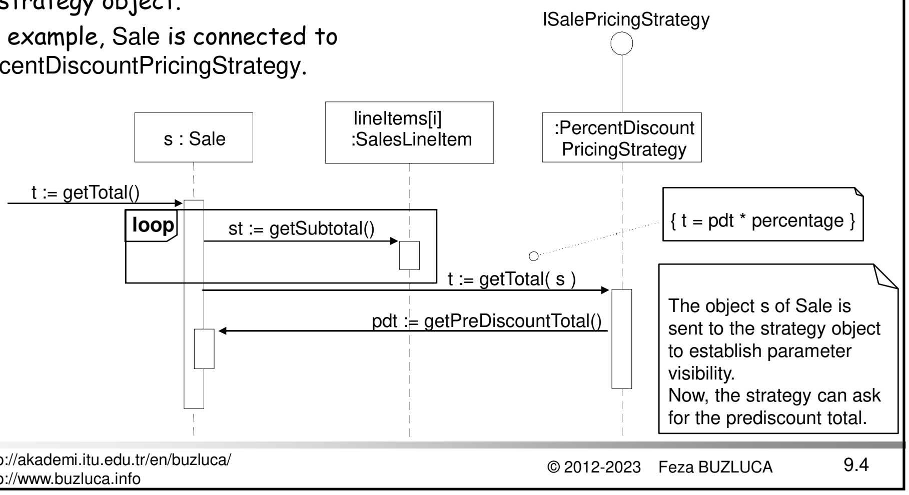
**Example:** The solution to the problem using the Strategy (contd)

A strategy object is attached to a context object, the object to which it applies the algorithm.

In this example, the context object is the Sale.

When a getTotal message is sent to a Sale object, it delegates some of the work to its strategy object.

For example, Sale is connected to PercentDiscountPricingStrategy.



The object s of Sale is sent to the strategy object to establish parameter visibility.
Now, the strategy can ask for the prediscount total.

## Underlying OO Principles of the Strategy pattern:

**Principle**: "*Find what varies and encapsulate it*"

This is one of the principles that the Strategy pattern is based on.

In our case study, varying parts are different discount strategies.

We separate these varying parts (pricing policies) from the stable part (Sale) of the system and encapsulate (group) them behind an abstract class (or interface in Java) (slide 9.3).

Remember "Protected Variations" (GRASP).

The details (types) of these strategies are hidden from the user (Sale).

The context object (Sale) must include a reference or a pointer to the interface (Java) or the base class (C++) of different strategies.

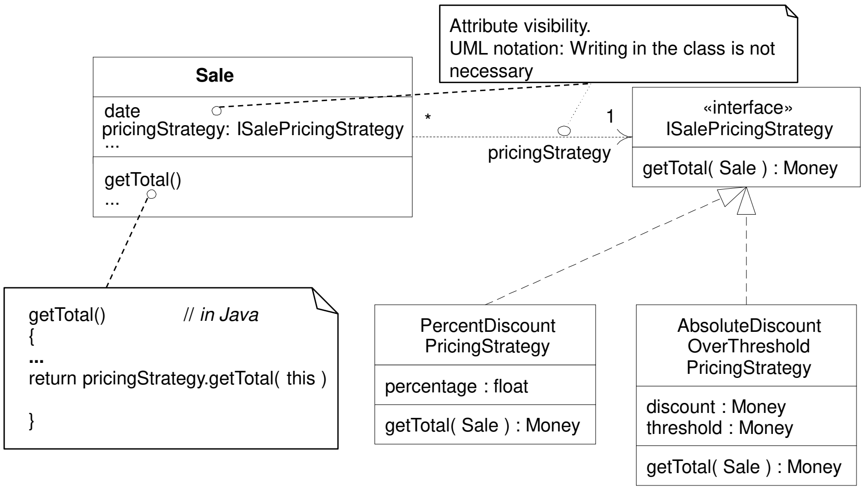
So, it gets attribute visibility to its strategy and can be connected to different strategy objects in runtime.

- Principle 1: "*Find what varies and encapsulate it*"

We found varying strategies and encapsulated them.

- Principle 2: "*Design to interface, not to an implementation*"

We designed the Sale according to the common interface of different strategies.



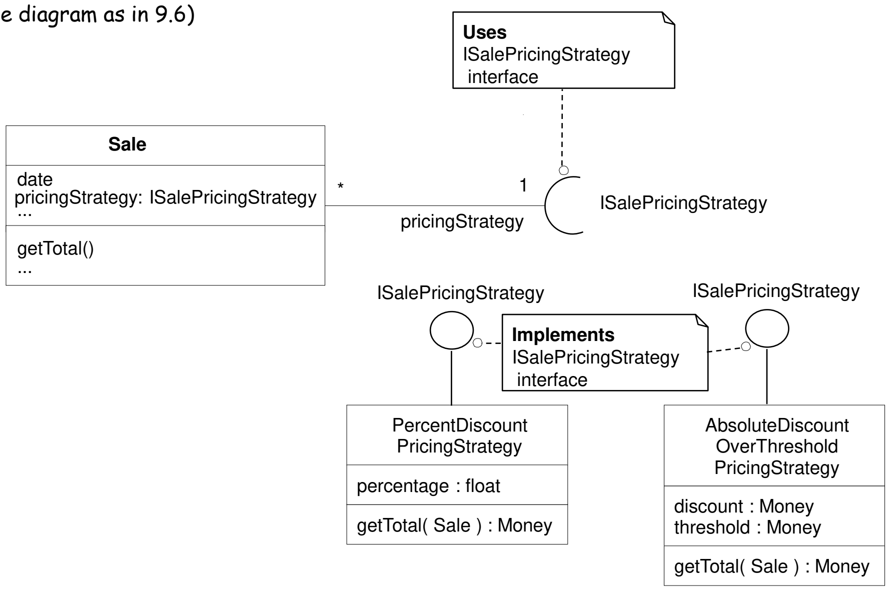
Attribute visibility.
UML notation: Writing in the class is not necessary

```
getTotal()              // in Java
{
...
return pricingStrategy.getTotal( this )

}
```

UML 2.X notation for interface *implementation* and *usage.*

(Same diagram as in 9.6)



**Uses**
ISalePricingStrategy
interface

**Sale**

date
pricingStrategy: ISalePricingStrategy
...

getTotal()
...

*

1

pricingStrategy

ISalePricingStrategy

ISalePricingStrategy

ISalePricingStrategy

**Implements**
ISalePricingStrategy
interface

PercentDiscount
PricingStrategy

percentage : float

getTotal( Sale ) : Money

AbsoluteDiscount
OverThreshold
PricingStrategy

discount : Money
threshold : Money

getTotal( Sale ) : Money

**Creating strategies (Factory):**

There are two problems in the POS system related to the pricing rules.

1. Discount policies (algorithms) for sale can vary (percentage, absolute, etc.).
2. Conditions to select the policies can vary (Monday, total > 200TL, customer).

The first problem is solved using the strategy pattern.

Details of the second problem:

- How to decide which strategy to use (create).
- Where should the code be about the conditions?
- How to establish visibility between the context object and the strategy object.

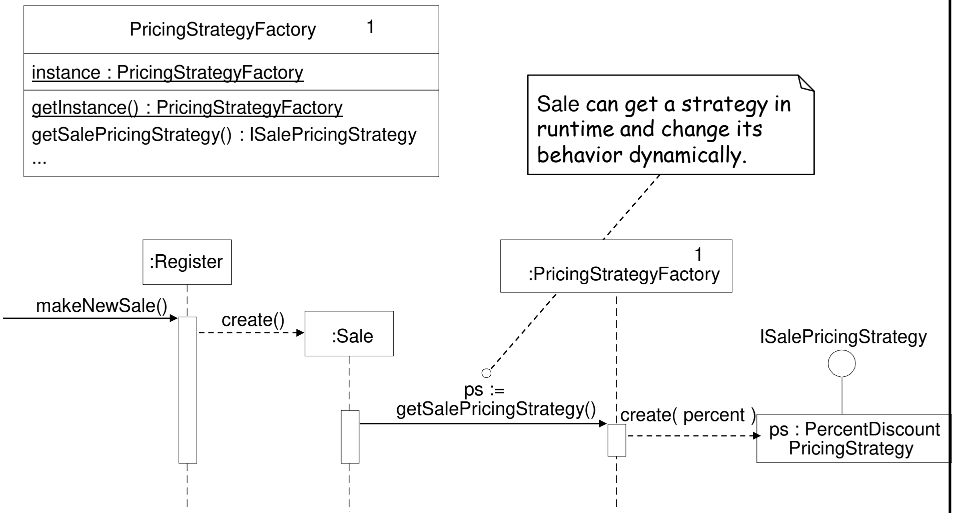
**The Factory** pattern can be applied to create the necessary strategy object.

A PricingStrategyFactory can be responsible for creating strategies.

The new factory is different from the ServicesFactory (for adapters).

This supports the goal of High Cohesion; each factory is focused only on creating a related family of objects.

## Creating strategies using a Factory:

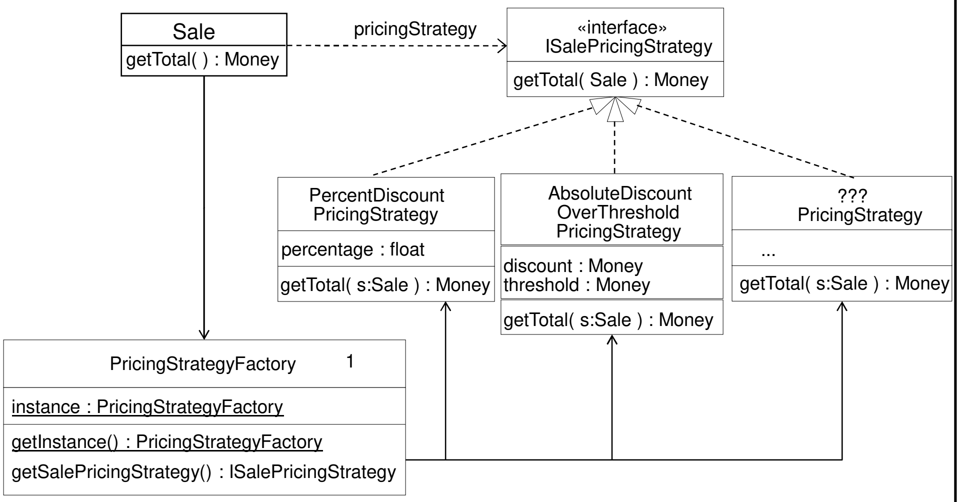


Sale can get a strategy in runtime and change its behavior dynamically.

Now, Sale is connected to an object PercentDiscountPricingStrategy.

Sale can access the discount algorithm using the pointer ps, as shown in 9.4.

## Factory and strategies:

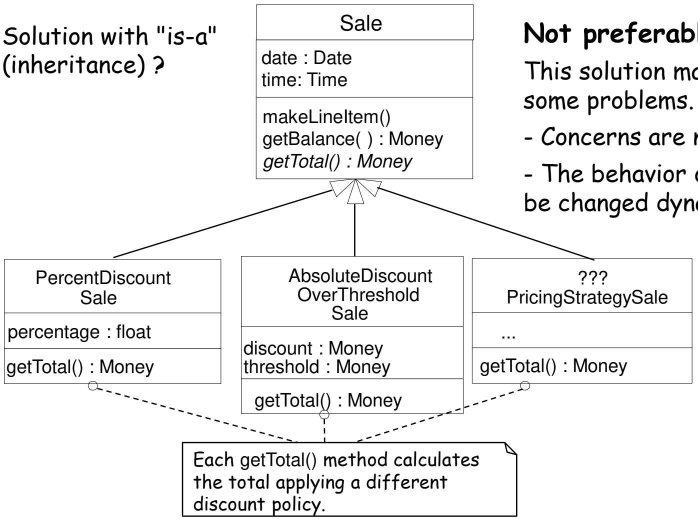


**Discussion: *Favor composition over inheritance* principle**

Is it possible to solve the same problem using Inheritance?

We assume that we have different Sale classes with various pricing policies.

Solution with "is-a" (inheritance) ?



**Not preferable!**

This solution may work, but it has some problems.

- Concerns are not separated.

- The behavior of objects cannot be changed dynamically.

**Discussion: Favor composition over inheritance principle**

**Disadvantages** of the solution with **inheritance** (is-a relation):

- Concerns are not separated: In the real world, we have only Sale classes (not different types). Various tasks are mixed in the same class.
- Inflexibility: If we create a Sale object of a specific type (for example PercentDiscountSale), we cannot change its behavior dynamically.
- We must decide on the pricing strategy during the creation of the sale.
- If we want to use another pricing strategy, we must delete the existing object and create a new one.

  There is a strong connection between the base class and the derived classes.

**Advantages** of the solution with **composition** (has-a relation) (Strategy):

- Separation of concerns: Each class focuses on its own task (Sale – Pricing Strategy)
- Flexibility: Sale can request a new strategy from the factory at any time and change its behavior dynamically.

  There is a weak connection (only a pointer or reference) between the context object (Sale) and strategies.

## The Open-Closed Principle

"Software entities (classes, modules, functions, etc.) should be **open for extension** but **closed for modification**".

- We should strive to write code that does not have to be changed every time the requirements change or new functionalities are added to the system.
- We should create flexible designs to take on new functionality to meet changing requirements without modifying the existing code.

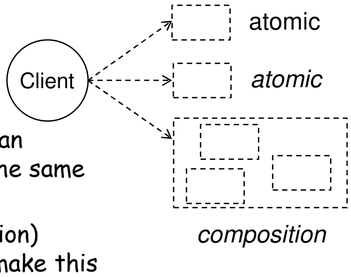
The OOP concept polymorphism and the principles "*Find what varies and encapsulate it*" and "*Design to interface not to an implementation*" support the "*Open-Closed Principle*".

Remember the Shape Library in slide 7.13. We can add a new shape arc without changing the existing code.

Similarly, we can get services from new external systems (using adapters) or add new policies (using strategies) to our system without modifying the existing code.

Later, we will cover other patterns based on the "*Open-Closed Principle*".

## The Composite Pattern (Structural)



Sometimes a client object may get a service from an individual (atomic) object; sometimes, it may get the same service from a composition (collection) of objects.

The client object treats them (atomic or composition) identically (polymorphically) and does not have to make this distinction.

**Definition:**

**Problem:** How to treat the composition structure of objects the same way (polymorphically) as a non-composite (atomic) object?

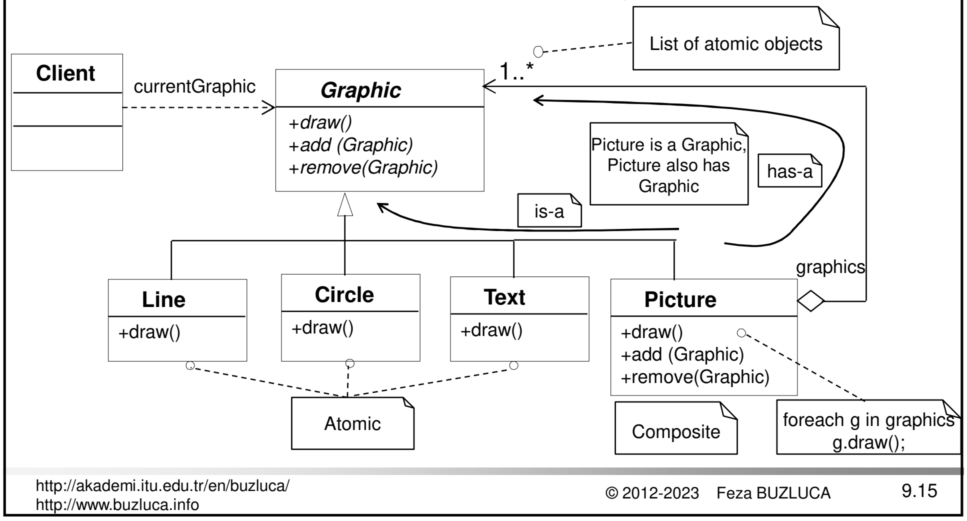
**Solution:** Define classes for composite and atomic objects so that they implement the same interface.

Add a list in the composite class that can include individual (atomic) objects.

**Example:** (From the book of the GoF)

In this example, we have *atomic* shape objects (Line, Circle, Text) and a *composite* object (Picture) that consists of atomic shape objects.

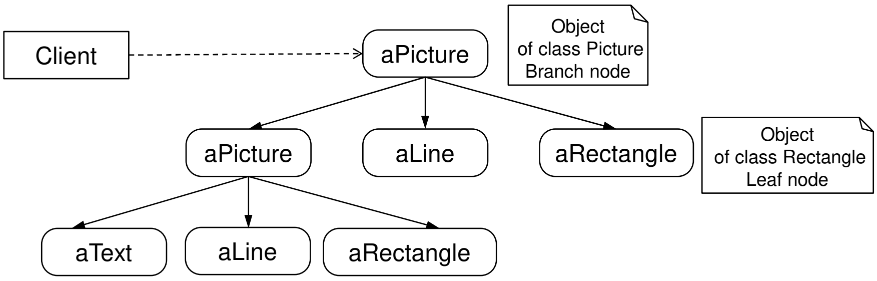
The class Client can get the same service (draw) from an *atomic* object (Line, Circle, Text) and at the same time from a *composite* object (Picture).



**Example:** (contd)

Objects can be composed into tree structures to represent part-whole hierarchies.
Composite lets clients treat individual objects (leaf nodes) and compositions of objects (branch nodes) uniformly.

The following diagram shows a typical composite object structure of recursively composed Graphic objects.



Atomic objects are leaf nodes, and composite objects are branch nodes of the tree.

**Example:** (From Larman)

How do we handle the case of multiple conflicting pricing policies?

For example, suppose that a store has the following policies:

- On Monday, there is 10TL off purchases over 100TL
- Preferred customer discount of 15%.
- Buy the product of the day, and get a 5% discount on everything.

If a preferred customer buys the product of the day and spends 150TL on Monday, what pricing policy should be applied?

Components of the problem:

1. Objects of the Sale class are sometimes connected to a single pricing strategy (atomic) and sometimes to a collection (composition) of strategies.

   The composite strategy solves this part of the problem.
2. The pricing strategies depend on different attributes of the Sale: Date, total, customer type, and a particular line item product.
3. Different strategies are conflicting.

We need to find solutions also for 2 and 3.

**Solution:**

We create a composite class CompositePricingStrategy derived from the same base class (ISalePricingStrategy) as the atomic strategies.

This composite class can also contain other ISalesPricingStrategy objects.

A list in the CompositePricingStrategy class contains currently valid pricing strategies. (Composite pattern)

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How to handle different conflicting strategies in the composite object is another strategy. (Strategy pattern again)

For example, the CompositeBestForCustomerPricingStrategy can try all strategies in its list and apply the strategy which returns the lowest total.

Another composite strategy (not so realistic) can be CompositeBestForStorePricingStrategy, which returns the highest total.

We can attach either a composite CompositeBestForCustomerPricingStrategy object (which contains other strategies inside of it) or an atomic PercentDiscountPricingStrategy object to the Sale object.

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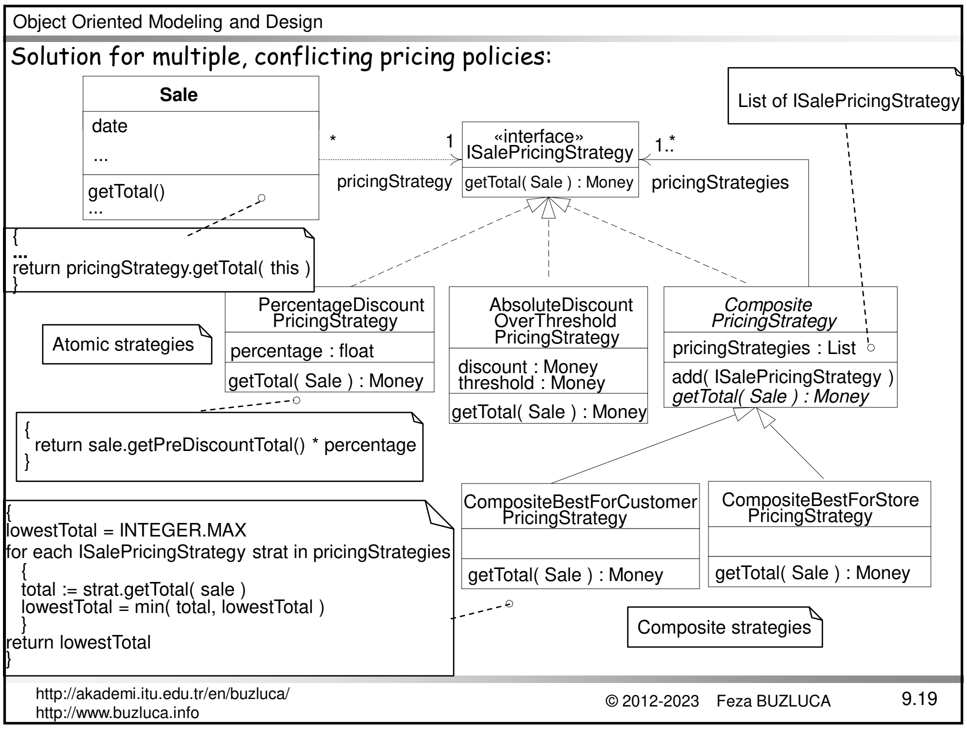
The Sale does not know or care if its pricing strategy is atomic or composite; they look the same to the Sale object because they are all derived from the same base class ISalePricingStrategy.

## Solution for multiple, conflicting pricing policies:



```
{
...
return pricingStrategy.getTotal( this )
}
```

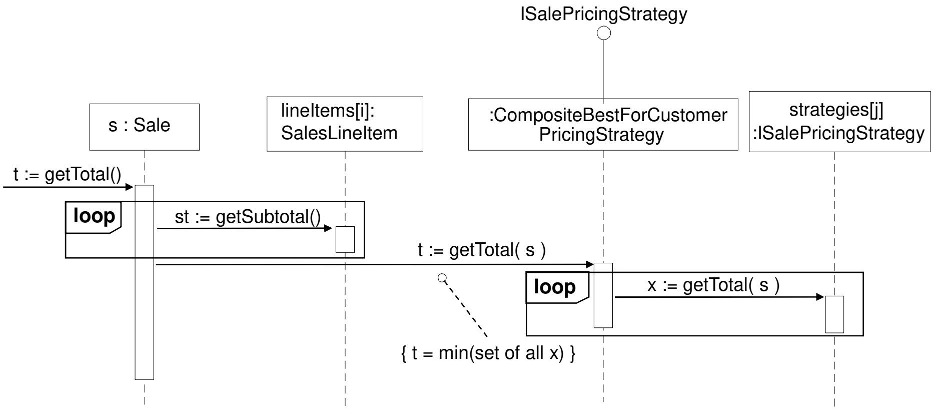
```
{
  return sale.getPreDiscountTotal() * percentage
}
```

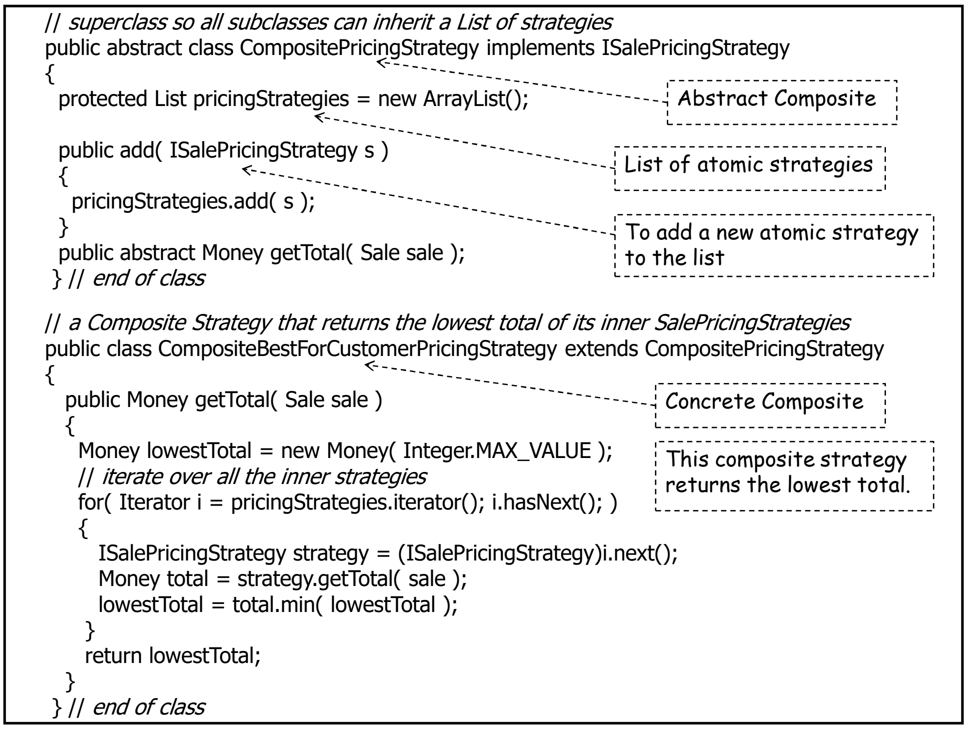
```
{
lowestTotal = INTEGER.MAX
for each ISalePricingStrategy strat in pricingStrategies
  {
  total := strat.getTotal( sale )
  lowestTotal = min( total, lowestTotal )
  }
return lowestTotal
}
```

## Collaboration with a Composite:

Sale can be attached to any object that implements the ISalePricingStrategy interface and understands the getTotal message.

**Example:** A CompositeBestForCustomerPricingStrategy object is attached to Sale.





```
// superclass so all subclasses can inherit a List of strategies
public abstract class CompositePricingStrategy implements ISalePricingStrategy
{
  protected List pricingStrategies = new ArrayList();

  public add( ISalePricingStrategy s )
  {
    pricingStrategies.add( s );
  }
  public abstract Money getTotal( Sale sale );
 } // end of class

// a Composite Strategy that returns the lowest total of its inner SalePricingStrategies
public class CompositeBestForCustomerPricingStrategy extends CompositePricingStrategy
{
   public Money getTotal( Sale sale )
   {
     Money lowestTotal = new Money( Integer.MAX_VALUE );
     // iterate over all the inner strategies
     for( Iterator i = pricingStrategies.iterator(); i.hasNext(); )
     {
        ISalePricingStrategy strategy = (ISalePricingStrategy)i.next();
        Money total = strategy.getTotal( sale );
        lowestTotal = total.min( lowestTotal );
      }
      return lowestTotal;
   }
 } // end of class
```

Abstract Composite

List of atomic strategies

To add a new atomic strategy to the list

Concrete Composite

This composite strategy returns the lowest total.

### Creating Multiple Sale Pricing Strategies

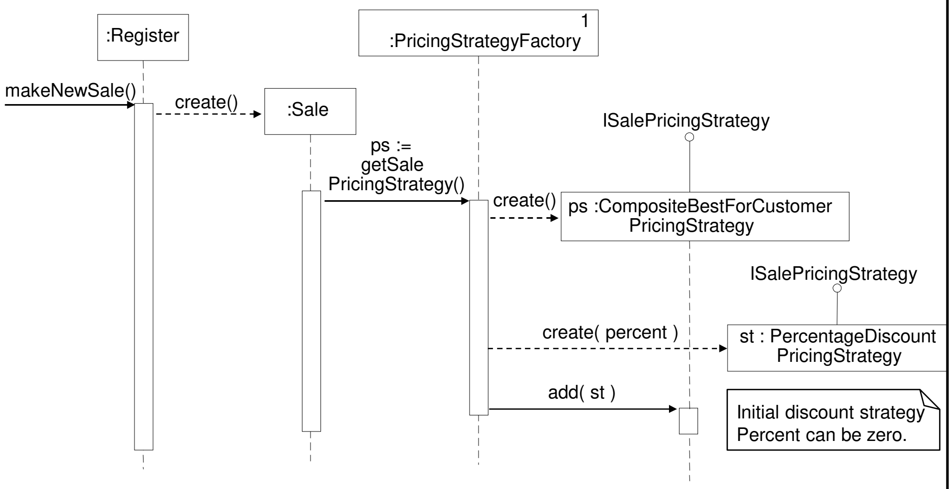
When an object of the Sale is created, it can request a strategy from the factory PricingStrategyFactory.

According to current conditions, the factory can decide to create a composite strategy such as the CompositeBestForCustomerPricingStrategy.

Initially, the factory can add the present moment's store discount policy (which could be set to 0% discount if none is active), such as some PercentageDiscountPricingStrategy, to the composite object.

Then, if another pricing strategy is discovered at a later step in the scenario (such as preferred customer discount), it will be easy to add it to the composite using the CompositePricingStrategy.add method.

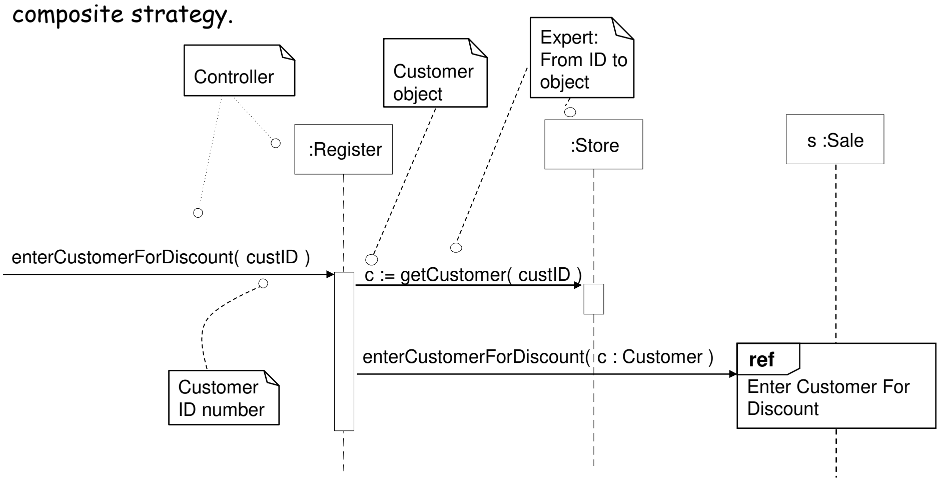
## Example: Creating Multiple Sale Pricing Strategies

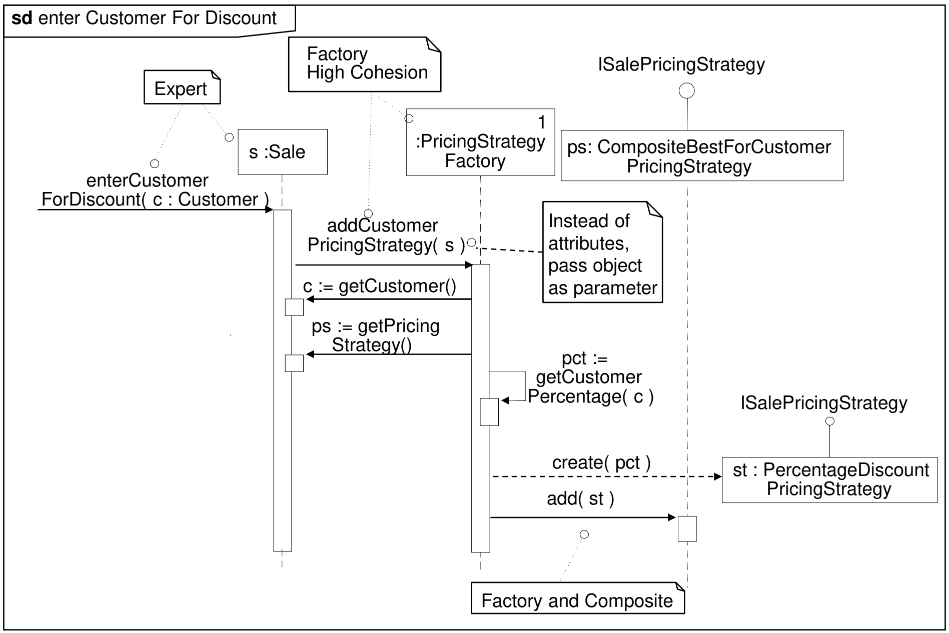


## Example: Creating the pricing strategy for a preferred customer discount:

If there are preferred customers in this system, we need to handle a new system operation: enterCustomerForDiscount

If there is a valid discount for this customer, it needs to be added to the composite strategy.





sd enter Customer For Discount

Expert

Factory
High Cohesion

ISalePricingStrategy

s :Sale

1
:PricingStrategy
Factory

ps: CompositeBestForCustomer
PricingStrategy

enterCustomer
ForDiscount( c : Customer )

addCustomer
PricingStrategy( s )

Instead of attributes, pass object as parameter

c := getCustomer()

ps := getPricing
Strategy()

pct :=
getCustomer
Percentage( c )

ISalePricingStrategy

create( pct )

st : PercentageDiscount
PricingStrategy

add( st )

Factory and Composite

## Considering principles and patterns in the design about customer discount

- Why does the Register not send a message to the PricingStrategyFactory, to create this new pricing strategy and then pass it to the Sale?

  The reason is to support *Low Coupling*. The Sale is already coupled with the factory.

  Furthermore, the Sale is the *Information Expert* that knows its current pricing strategy.

- Why should we transform the customerID (perhaps a number) into a Customer object?

  It doesn't have a pattern name, but this is a common practice in object design to transform keys and IDs for things into actual objects.

  Having an actual Customer object containing information about the customer, which can have functions, becomes beneficial and flexible as the design grows.

  For example, itemID is transformed into a ProductDescription object in the enterItem operation.

- customerID is transformed into a Customer object by the Store.

  Reason: By *Information Expert* and the goal of the *low representational gap*, the Store can know all the Customers.

  The Register asks the Store because the Register already has attribute visibility to the Store (from earlier design work).

### Considering principles and patterns in the design (contd)

- Passing aggregate object as a parameter:

  In the addCustomerPricingStrategy(s: Sale) message, we pass a reference to the Sale object s to the factory. Then the factory asks for the Customer and PricingStrategy from the Sale.

  Why d not we send just these two parameters to the factory?

  Principle: Instead of individual attributes or child objects, pass the aggregate object (actually the reference) that contains child objects (or attributes).

  Reason: Following this principle increases flexibility because the factory can collaborate with the entire Sale in ways we may not have previously considered necessary.

  In future design steps, new parameters (attributes) may be necessary.

  In this case, we don't need to change the interfaces of our methods; the factory can get them from Sale by calling the necessary get functions.

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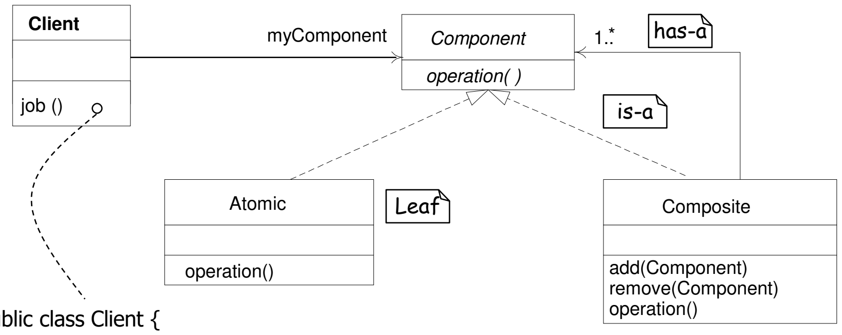
  **Note:** The composite pattern is not used only with the strategies.

  This pattern provides that a client object treats individual objects (atomic) and group of objects (composition) identically (polymorphically), and does not have to make this distinction.

### The General Structure of the Composite Pattern:



```
public class Client {
  private Component myComponent;  // reference (or pointer)

   public job()
   {
      ......
      myComponent.operation();  // it can be atomic (leaf) or composite (branch node)
   }

 }
```