# Software Design and Construction 1
# SOFT2201 / COMP9201



## Behavioural Design Patterns

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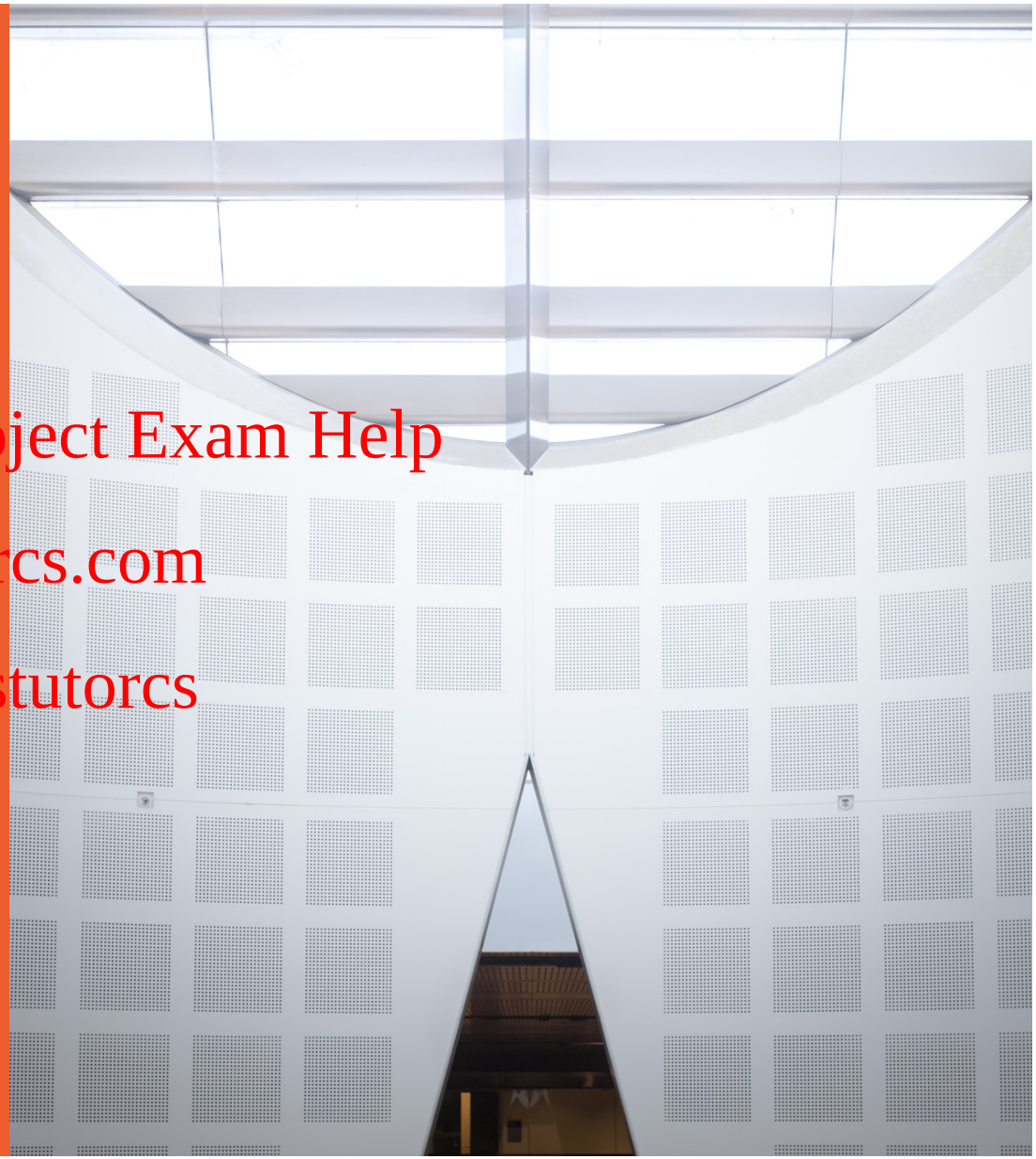

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# Agenda

- Behavioral Design Patterns
  - Strategy
  - State

# Behavioural Design Patterns



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# Behavioural Patterns

- Concerned with algorithms and the assignment of responsibilities between objects
- Describe patterns of objects and class, and communication between them
- Simplify complex control flow that's difficult to follow at run-time
  - Concentrate on the ways objects are interconnected
- **Behavioural Class Patterns (SOFT3202)**
  - Use inheritance to distribute behavior between classes (algorithms and computation)
- **Behavioural Object Patterns**
  - Use object composition, rather than inheritance. E.g., describing how group of peer objects cooperate to perform a task that no single object can carry out by itself
  - Question: how peer objects know about each other?

# Behavioural Patterns (GoF)

| Pattern Name | Description |
|---|---|
| **Strategy** | **Define a family of algorithms, encapsulate each one, and make them interchangeable (let algorithm vary independently from clients that use it)** |
| Observer | Define a one-to-many dependency between objects so that when one object changes, all its dependents are notified and updated automatically |
| Memento | Without violating encapsulation, capture and externalize an object's internal state so that the object can be restored to this state later |
| Command | Encapsulate a request as an object, thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operations |
| **State** | **Allow an object to alter its behaviour when its internal state changes. The object will appear to change to its class** |
| Visitor | Represent an operation to be performed on the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates |
| Other patterns | Interpreter, Iterator, Mediator, Chain of Responsibility, Template Method |

# Strategy Design Pattern



Object Behavioural Pattern



Algorithm design through encapsulation



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# Strategy Design Pattern

- **Purpose/Intent**
  - Define a family of algorithms, encapsulate each one, and make them interchangeable
  - Let the algorithm vary independently from clients that use it
- **Known as**
  - Policy
- **Motivation Scenario**
  - Design for varying but related algorithms that are suitable for different contexts
    - Ability to change these algorithms

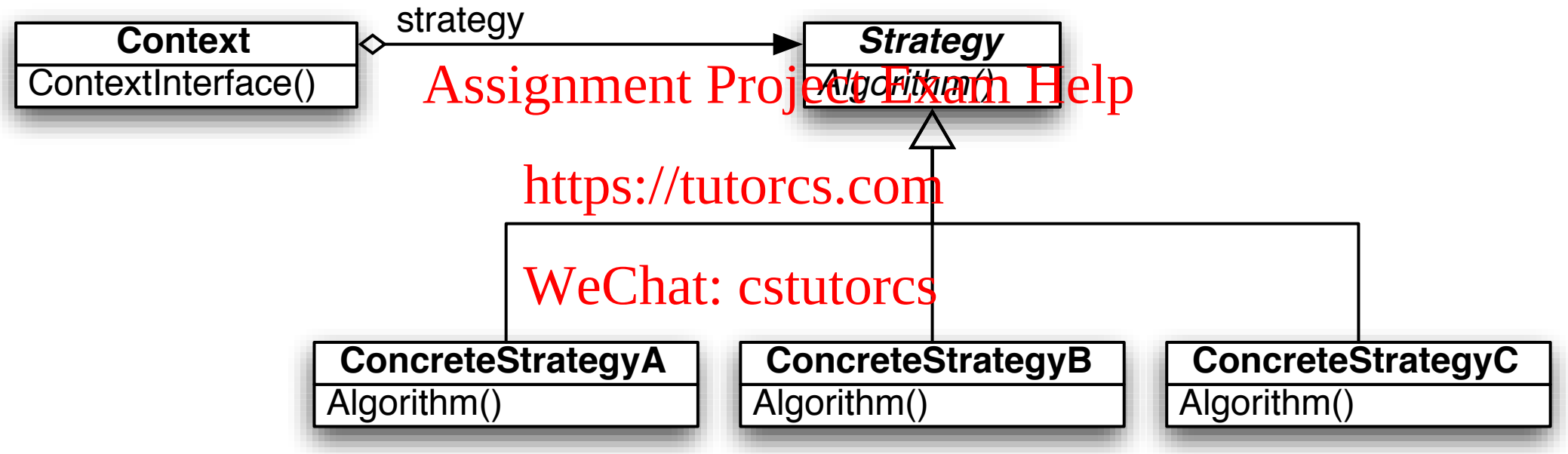
# Strategy – Applicability

- Many related classes differ only in their behavior
- You need different variant of an algorithm
- An algorithm uses data that should be hidden from its clients
- A class defines many behaviors that appear as multiple statements in its operations

# Strategy – Example (Text Viewer)

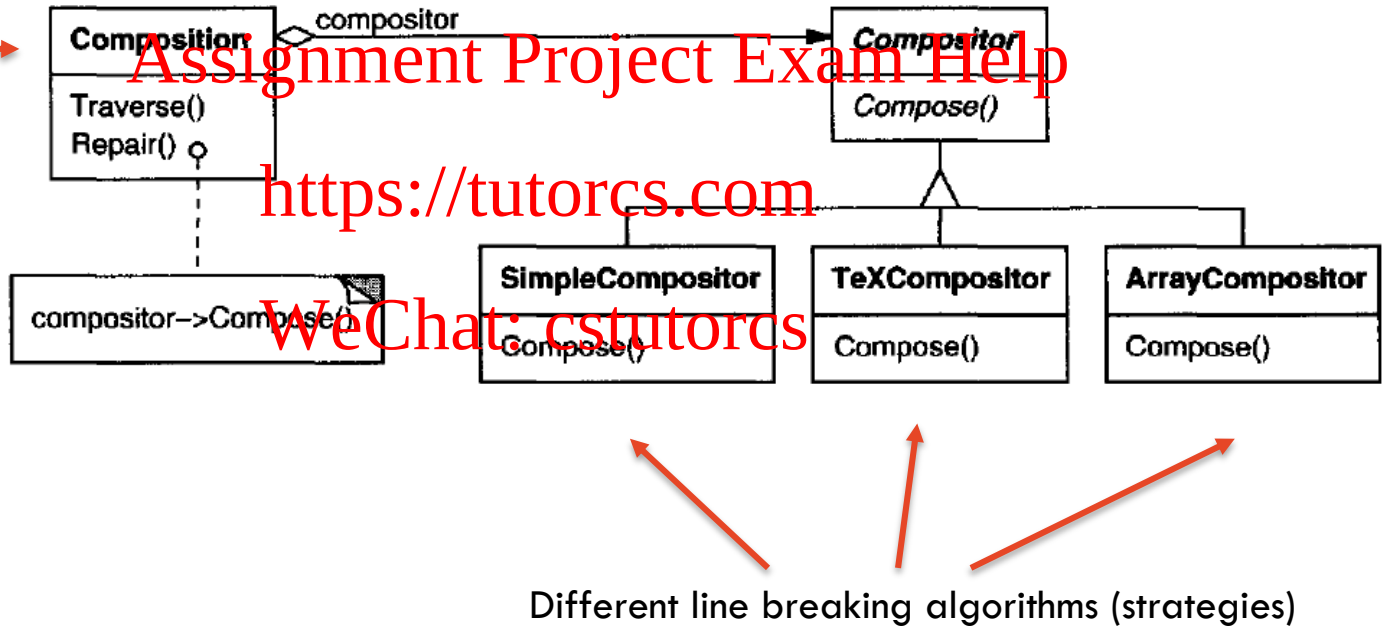
- Many algorithms for breaking a stream of text into lines
- Problem: hard-wiring all such algorithms into the classes that require them
  - More complex and harder to maintain clients (more line breaking algorithms)
  - Not all algorithms will be needed at all times

# Strategy – Structure



# Strategy – Example (Text Viewer)

Maintain & update the line breaks of text




Different line breaking algorithms (strategies)

# Strategy – Participants

| Participant | Goals |
| --- | --- |
| Strategy (Compositor) | Declares an interface common to all supported algorithms<br>Used by context to call the algorithm defined by ConcereteStrategy |
| ConcereteStrategy (SimpleCompositor, TeXCompositor, etc) | Implements the algorithm using the Strategy interface |
| Context (Composition) | Is configured with a ConcereteStrategy object<br>Maintains a reference to a Strategy object<br>May define an interface that lets Strategy access its data |

# Strategy – Collaborations

- Strategy and Context interact to implement the chosen algorithm
  - A context may pass all data required by the algorithm to the Strategy
  - The context can pass itself as an argument to Strategy operations
- A context forwards requests from its clients to its strategy
  - Clients usually create and pass a ConcreteStrategy object to the context; thereafter, clients interact with the context exclusively

# Strategy – Consequences (Benefits)

- Family of related algorithms (behaviors) for context to reuse
- Alternative to sub-classing
  - Why not sub-classing a Context class directly to give it different behaviors?
- Strategies eliminate conditional statements
- Provide choice of different implementation of the same behavior

# Strategy – Consequences (Drawbacks)

- Clients must be aware of different strategies
  - Understand how strategies differ
- Communicate overhead between Strategy and Context
  - Strategy interface is shared by all ConcreteStrategy classes whether the algorithms they implement are trivial or complex
- Increased number of objects in an application
  - Can be reduced by implementing strategies as stateless objects that context can share
  - Strategy objects often make good flyweight (sharing strategies)

# Strategy – NextGen PoS System

- **Design problem:** how to provide more complex pricing logic, e.g., store-wide discount for the day, senior citizen discounts

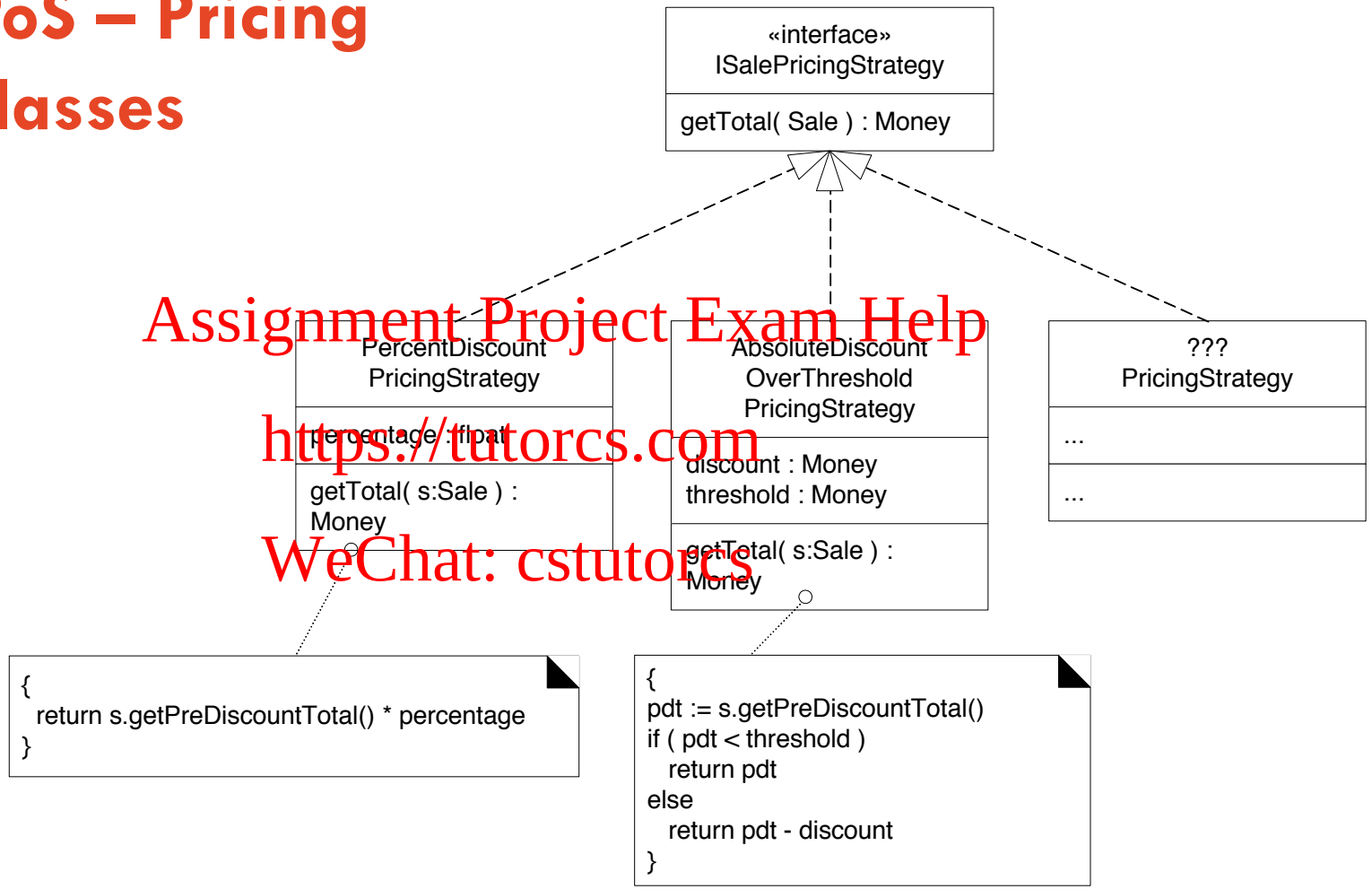


- The pricing strategy (or policy) for a sale can vary:
  - 10% of all sales during a specific period
  - $10 off if the total sale is greater than $200
  - Other variations



- How do we design our system to accommodate such varying pricing policies?

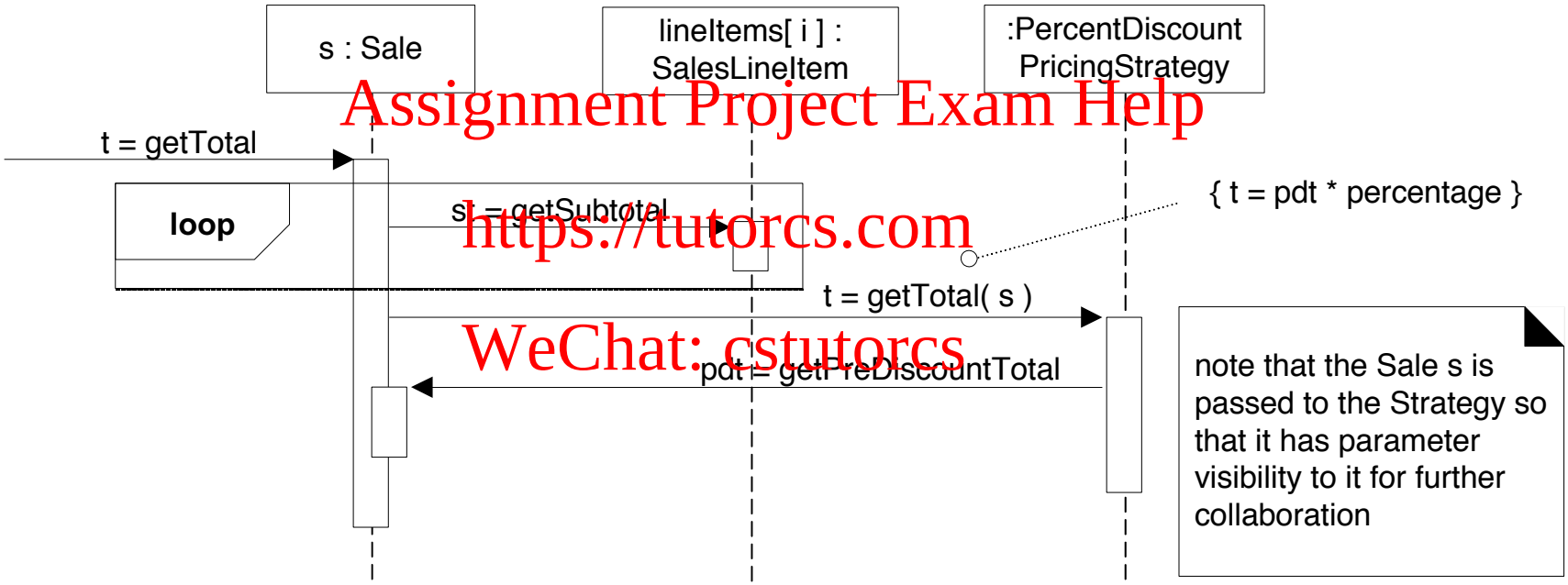
# NextGen PoS – Pricing Strategy Classes



# Strategy Pattern – NextGen PoS System

- Create multiple *SalesePricingStrategy* classes, each with a polymorphic *getTotal* method
- Each *getTotal* method takes the *Sale* object as a parameter
  - The pricing strategy object can find the pre-discount price from the Sale, and they apply the discounting policy
- The implementation of each getTotal method will be different
  - E.g., *PercentDiscountPricingStrategy* will discount by a percentage

# PoS System – Strategy POS Collaboration



# PoS System – Strategy POS Collaboration

- A strategy is attached to the *Sale* object (context object)

- The *Sale* object delegates some of the work to its strategy object
  - The message to the context and strategy objects is not required to be the same (e.g., getTotal)
  - The Sale object passes a reference to itself on to the strategy object

# State Design Pattern



Object Behavioural Pattern



Taking control of objects from the inside



A structured way to control the internal behaviour of an object

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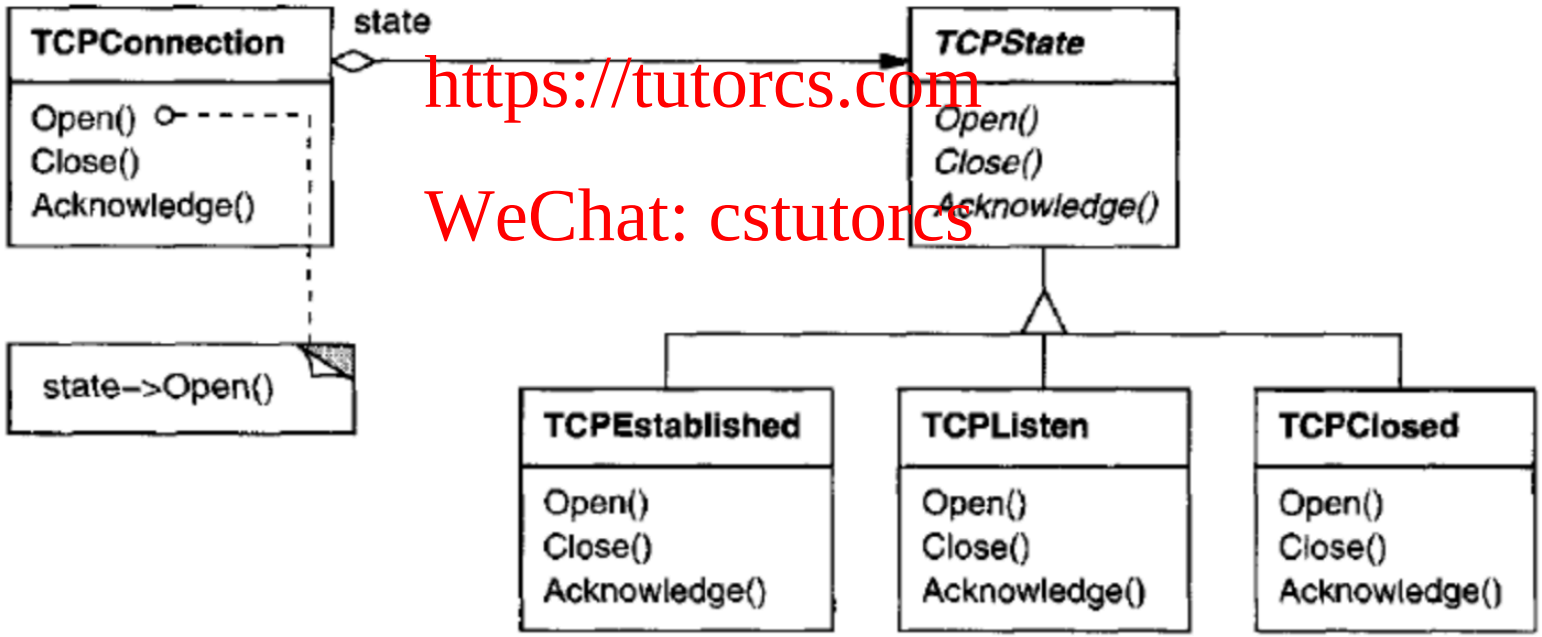
# State Design Pattern

- **Purpose/Intent**
  - Allow an object to change its behaviour when its internal state changes
  - The object will appear to change its class when the state changes
- **Known as**
  - Objects for States
- Motivating Scenario
  - We can use subtypes of classes with different functionality to represent different states, such as for a TCP connection with Established, Listening, Closed as states

# Motivating Scenario

- TCP network connection
- States: Established, Listening and Closed
- TCP connection responds based on its current state

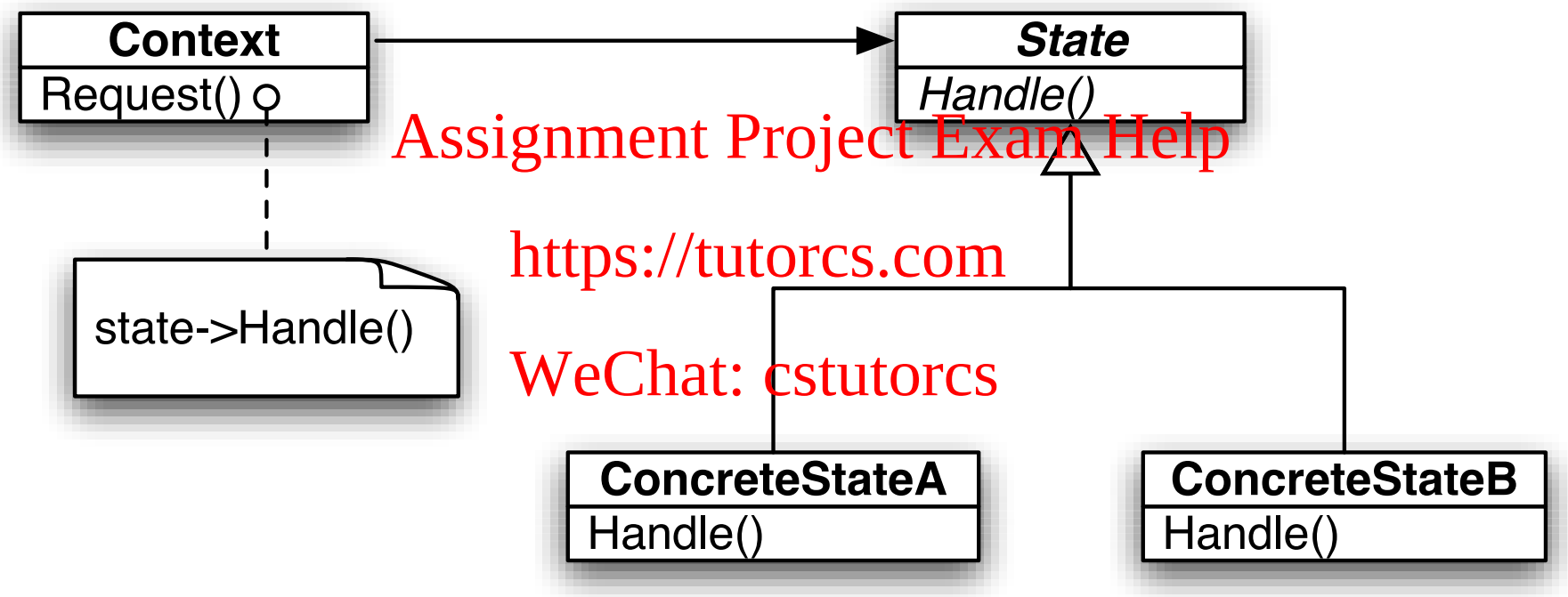




# State Design Pattern

- Applicability
  - Any time you need to change behaviours dynamically, i.e., the state of an object drives its behavior and change its behavior dynamically at run-time
  - There are multi-part checks of an object's state to determine its behaviour, i.e., operations have large, multipart conditional statements that depend on the object's state
- Benefits
  - Removes case or if/else statements depending on state, and replaces them with function calls; makes the state transitions explicit; permits states to be shared
- Limitations
  - Does require that all the states have to have their own objects

# State Pattern – Structure



# State Pattern – Participants

- Context (TCPConnection)
  - Defines the interface of interest to clients
  - Maintains an instance of a ConcreteState subclass that defines the current state
- State (TCPState)
  - Defines an interface for encapsulating the behaviour associated with a certain state of the Context
- ConcreteState subclasses (TCPEstablished, TCPListen, TCPClosed)
  - Each subclass implements a behaviour associated with a state of the Context

# State Pattern – Collaborations

- Context delegates state – specific requests to the current ConcreteState object



- A context may pass itself as an argument to the State object handling the request, so the State object access the context if necessary





- Context is the primary interface for clients
  - Clients can configure a context with State objects, so its clients don't have to deal with the State objects directly

- Either Context or the ConcreteState subclasses can decide which state succeeds another and under what circumstances

# State Pattern – Code Example

```
1  interface State {
2      void writeName(StateContext context, String name);
3  }
5  class LowerCaseState implements State {
6      @Override
7      public void writeName(StateContext context, String name) {
8          System.out.println(name.toLowerCase());
9          context.setState(new MultipleUpperCaseState());
10     }
11 }
12
13 class MultipleUpperCaseState implements State {
14     /* Counter local to this state */
15     private int count = 0;
16
17     @Override
18     public void writeName(StateContext context, String name) {
19         System.out.println(name.toUpperCase());
20         /* Change state after StateMultipleUpperCase's writeName() gets invoked twice */
21         if(++count > 1) {
22             context.setState(new LowerCaseState());
23         }
24     }
25 }
```

# State Pattern – Code Example

```
27 class StateContext {
28     private State state;
29
30     public StateContext() {
31         state = new LowerCaseState();
32     }
33
34     /**
35      * Set the current state.
36      * Normally only called by classes implementing the State interface.
37      * @param newState the new state of this context
38      */
39     void setState(State newState) {
40         state = newState;
41     }
42
43     public void writeName(String name) {
44         state.writeName(this, name);
45     }
46 }
```

# State Pattern – Code Example

```
48 public class StateDemo {
49     public static void main(String[] args) {
50         var context = new StateContext();
51
52         context.writeName("Monday");
53         context.writeName("Tuesday");
54         context.writeName("Wednesday");
55         context.writeName("Thursday");
56         context.writeName("Friday");
57         context.writeName("Saturday");
58         context.writeName("Sunday");
59     }
60 }
```



- What is the output of StateDemo?

# State Pattern – Consequences

- Localizes state-specific behaviour for different states
  - Using data values and context operations mark code maintenance difficult
  - State distribution across different subclasses useful when there are many states
  - Better code structure for state-specific code (better than monolithic)



- It makes state transition explicit
  - State transitions as variable assignments
  - State objects can protect the context from inconsistent state

- State objects can be shared
  - When the state they represent is encoded entirely in their type

# State Pattern – Implementation (1)

- Defining the state transitions
  - Let the state subclasses specify their successor state to make the transition (decentralized)
  - Achieves flexibility – easy to modify and extend the logic
  - Introduces implementation dependencies between subclasses



- Table-based state transitions
  - Look-up table that maps every possible input to a succeeding state
  - Easy to modify (transition data not the program code) but:
    - Less efficient than a functional call
    - Harder to understand the logic (transition criteria is less explicit)
    - Difficult to add actions to accompany the state transitions

# State Pattern – Implementation (2)

- When to create and destroy state objects?
  - Pre-create them and never destroy them
    - Useful for frequent state changes (save costs of re-creating states)
    - Context must keep reference to all states
  - Only when they are needed and destroyed them thereafter
    - States are not known at run-time and context change states frequently

# State Pattern – Implementation (3)

- Using dynamic inheritance
  - Changing the object's class at run-time is not possible in most OO languages
  - delegation-based languages allow changing the delegation target at run-time

# References


- Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides. 1995. *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA.

# Task for Week 6

- Submit weekly exercise on canvas before 23.59pm Sunday
- Well organize time and continue assignment 2
- Attend Helpdesk session if you have any questions/difficulties on implementation perspective

# What are we going to learn on week 7?

- Testing

- Not next week but the week after next week
  - Next week is mid-break week
  - no lecture and tutorials during mid-break week but Helpdesk session runs as normal at Wed/Thursday during mid-break week