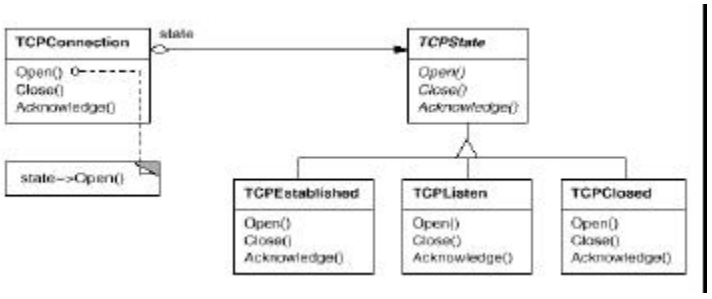
# The
# State and Strategy
# Patterns



## The State Pattern

- Intent
  - ⇨ Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.
- Motivation



## The State Pattern

- Applicability

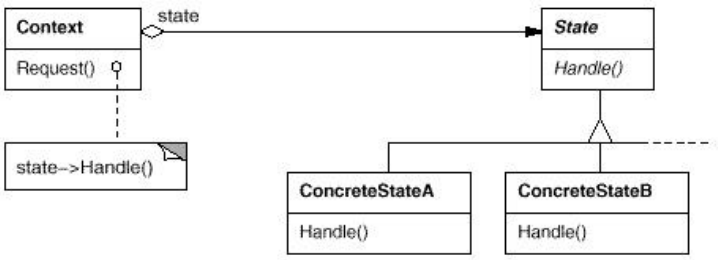
  Use the State pattern whenever:

  - ⇨ An object's behavior depends on its state, and it must change its behavior at run-time depending on that state
  - ⇨ Operations have large, multipart conditional statements that depend on the object's state. The State pattern puts each branch of the conditional in a separate class.



## The State Pattern

- Structure



## The State Pattern

- Consequences
  - ⇨ Benefits
    - ➡ Puts all behavior associated with a state into one object
    - ➡ Allows state transition logic to be be incorporated into a state object rather than in a monolithic if or switch statement
    - ➡ Helps avoid inconsistent states since state changes occur using just the one state object and not several objects or attributes
  - ⇨ Liabilities
    - ➡ Increased number of objects



## State Pattern Example 1

- Consider a class that has two methods, push() and pull(), whose behavior changes depending on the state of the object
- To send the push and pull requests to the object, we'll use the following GUI with "Push" and "Pull" buttons:


- The state of the object will be indicated by the color of the canvas in the top part of the GUI
- The states are: black, red, blue and green

## State Pattern Example 1 (Continued)

- First, let's do this without the State pattern:

```
/**
 * Class ContextNoSP has behavior dependent on its state.
 * The push() and pull() methods do different things
 *   depending on the state of the object.
 * This class does NOT use the State pattern.
 */
public class ContextNoSP  {

  // The state!
  private Color state = null;

  // Creates a new ContextNoSP with the specified state (color).
  public ContextNoSP(Color color) {state = color;}
  // Creates a new ContextNoSP with the default state
  public ContextNoSP() {this(Color.red);}
```



## State Pattern Example 1 (Continued)

```
  // Returns the state.
  public Color getState() {return state;}

  // Sets the state.
  public void setState(Color state) {this.state = state;}

  /**
   * The push() method performs different actions depending
   *   on the state of the object.  Actually, right now
   *   the only action is to make a state transition.
   */
  public void push() {
    if (state == Color.red) state = Color.blue;
    else if (state == Color.green) state = Color.black;
    else if (state == Color.black) state = Color.red;
    else if (state == Color.blue) state = Color.green;
  }
```

## State Pattern Example 1 (Continued)

```
    /**
     * The pull() method performs different actions depending
     *   on the state of the object.  Actually, right now
     *   the only action is to make a state transition.
     */
    public void pull() {
      if (state == Color.red) state = Color.green;
      else if (state == Color.green) state = Color.blue;
      else if (state == Color.black) state = Color.green;
      else if (state == Color.blue) state = Color.red;
    }

}
```



## State Pattern Example 1 (Continued)

- Here's part of the GUI test program:

```
/**
 * Test program for the ContextNoSP class
 * which does NOT use the State pattern.
 */
public class TestNoSP extends Frame
  implements ActionListener  {

  // GUI attributes.
  private Button pushButton = new Button("Push Operation");
  private Button pullButton = new Button("Pull Operation");
  private Button exitButton = new Button("Exit");
  private Canvas canvas = new Canvas();

  // The Context.
  private ContextNoSP context = null;
```

## State Pattern Example 1 (Continued)

```
public TestNoSP() {
  super("No State Pattern");
  context = new ContextNoSP();
  setupWindow();
}

private void setupWindow() { // Setup GUI }

// Handle GUI actions.
public void actionPerformed(ActionEvent event) {
  Object src = event.getSource();
  if (src == pushButton) {
    context.push();
    canvas.setBackground(context.getState());
  }
```

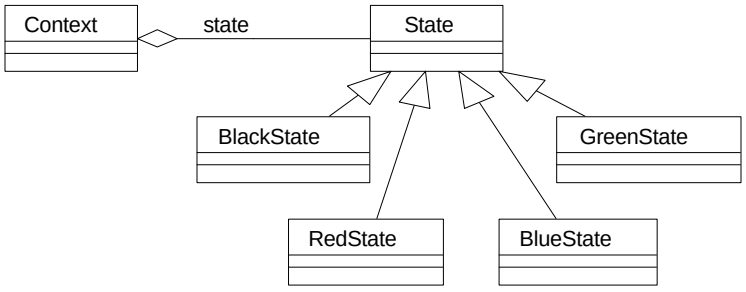


## State Pattern Example 1 (Continued)

```
    else if (src == pullButton) {
      context.pull();
      canvas.setBackground(context.getState());

    }
    else if (src == exitButton) {
      System.exit(0);
    }
  }

  // Main method.
  public static void main(String[] argv) {
    TestNoSP gui = new TestNoSP();
    gui.setVisible(true);
  }

}
```

## State Pattern Example 1 (Continued)

- Now let's use the State pattern!
- Here's the class diagram:






## State Pattern Example 1 (Continued)

- First, we'll define the abstract State class:

```
/**
 * Abstract class which defines the interface for the
 *   behavior of a particular state of the Context.
 */
public abstract class State {
  public abstract void handlePush(Context c);
  public abstract void handlePull(Context c);
  public abstract Color getColor();
}
```

- Next, we'll write concrete State classes for all the different states: RedState, BlackState, BlueState and GreenState

## State Pattern Example 1 (Continued)

- For example, here's the BlackState class:

```
public class BlackState extends State {
  // Next state for the Black state:
  //   On a push(), go to "red"
  //   On a pull(), go to "green"

  public void handlePush(Context c) {
    c.setState(new RedState());
  }

  public void handlePull(Context c) {
    c.setState(new GreenState());
  }

  public Color getColor() {return (Color.black);}
}
```



## State Pattern Example 1 (Continued)

- And, here's the new Context class that uses the State pattern and the State classes:

```
/**
 * Class Context has behavior dependent on its state.
 * This class uses the State pattern.
 * Now when we get a pull() or push() request, we
 *   delegate the behavior to our contained state object!
 */
public class Context {

  // The contained state.
  private State state = null;  // State attribute

  // Creates a new Context with the specified state.
  public Context(State state) {this.state = state;}
```

## State Pattern Example 1 (Continued)

```
    // Creates a new Context with the default state.
    public Context() {this(new RedState());}

    // Returns the state.
    public State getState() {return state;}

    // Sets the state.
    public void setState(State state) {this.state = state;}
```



## State Pattern Example 1 (Continued)

```
    /**
     * The push() method performs different actions depending
     *   on the state of the object.  Using the State pattern,
     *   we delegate this behavior to our contained state object.
     */
    public void push() {state.handlePush(this);}

    /**
     * The pull() method performs different actions depending
     *  on the state of the object.  Using the State pattern,
     *  we delegate this behavior to our contained state object.
     */
    public void pull() {state.handlePull(this);}

}
```

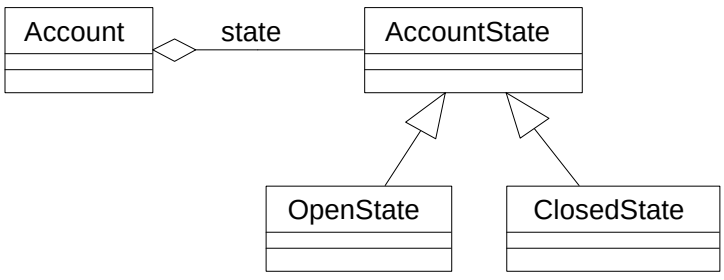
## The State Pattern

- Implementation Issues
  - ⇨ Who defines the state transitions?
    - ➟ The Context class => ok for simple situations
    - ➟ The ConcreteState classes => generally more flexible, but causes implementation dependencies between the ConcreteState classes
    - ➟ Example 1 has the ConcreteState classes define the state transitions
  - ⇨ When are the ConcreteState objects created?
    - ➟ Create ConcreteState objects as needed
    - ➟ Create all ConcreteState objects once and have the Context object keep references to them
    - ➟ Example 1 creates them as needed
  - ⇨ Can't we just use a state-transition table for all this?
    - ➟ Harder to understand
    - ➟ Difficult to add other actions and behavior



## State Pattern Example 2

- Situation: A bank account can change from an open account to a closed account and back to an open account again. The behavior of the two types of accounts is different.
- Solution: Use the State pattern!



## State Pattern Example 3 - SPOP

- This example comes from Roger Whitney, San Diego State University
- Consider a simplified version of the Post Office Protocol used to download e-mail from a mail server
- Simple POP (SPOP) supports the following command:
  - ⇨ USER username
    - ➡ The USER command with a username must be the first command issued
  - ⇨ PASS password
    - ➡ The PASS command with a password or the QUIT command must come after USER. If the username and password are valid, then the user can use other commands.
  - ⇨ LIST <message number>
    - ➡ The LIST command returns the size of all messages in the mail box. If the optional message number is specified, then it returns the size of that message.



## State Pattern Example 3 - SPOP (Continued)

- ⇨ RETR <message number>
  - ➡ The RETR command retrieves all message in the mail box. If the optional message number is specified, then it retrieves that message.
- ⇨ QUIT
  - ➡ The QUIT command updates the mail box to reflect transactions taken, then logs the user out.

## State Pattern Example 3 - SPOP (Continued)

- Here's a version of an SPop class without using the State pattern:

```
public class SPop {
  static final int QUIT = 1;
  static final int HAVE_USER_NAME = 2;
  static final int START = 3;
  static final int AUTHORIZED = 4;
  private int state = START;
  String userName;
  String password;
```



## State Pattern Example 3 - SPOP (Continued)

```
  public void user(String userName) {
    switch (state) {
      case START: {
        this.userName = userName;
        state = HAVE_USER_NAME;
        break;
      }
      default: { // Invalid command
        sendErrorMessageOrWhatEver();
        endLastSessionWithoutUpdate();
        userName = null;
        password = null;
        state = START;
      }
    }
  }
```

## State Pattern Example 3 - SPOP (Continued)

```
public void pass(String password) {
  switch (state) {
    case HAVE_USER_NAME: {
      this.password = password;
      if (validateUser())
        state = AUTHORIZED;
      else {
        sendErrorMessageOrWhatEver();
        userName = null;
        password = null;
        state = START;
      }
    }
```

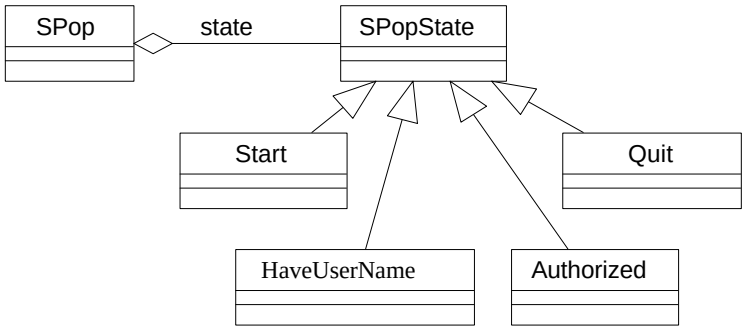


## State Pattern Example 3 - SPOP (Continued)

```
    default: {  // Invalid command
      sendErrorMessageOrWhatEver();
      endLastSessionWithoutUpdate();
      state = START;
    }
  }
 }
 ...
}
```

## State Pattern Example 3 - SPOP (Continued)

- Now let's use the State pattern!
- Here's the class diagram:






## State Pattern Example 3 - SPOP (Continued)

- First, we'll define the SPopState class. Notice that this class is a concrete class that defines default actions.

```
public class SPopState {

  public SPopState user(String userName) {default action here}

  public SPopState pass(String password) {default action here}

  public SPopState list(int messageNumber) {default action here}

  public SPopState retr(int messageNumber) {default action here}

  public SPopState quit() {default action here}

}
```

## State Pattern Example 3 - SPOP (Continued)

- Here's the Start class:

```
public class Start extends SPopState {

  public SPopState user(String userName) {
    return new HaveUserName(userName);
  }

}
```



## State Pattern Example 3 - SPOP (Continued)

- Here's the HaveUserName class:

```
public class HaveUserName extends SPopState {

  String userName;

  public HaveUserName(String userName) {
    this.userName = userName;
  }

  public SPopState pass(String password) {
    if (validateUser(userName, password)
      return new Authorized(userName);
    else
      return new Start();
  }
}
```

## State Pattern Example 3 - SPOP (Continued)

- Finally, here is the SPop class that uses these state classes:

```
public class SPop {
  private SPopState state = new Start();

  public void user(String userName) {
    state = state.user(userName);
  }

  public void pass(String password) {
    state = state.pass(password);
  }

  public void list(int messageNumber) {
    state = state.list(messageNumber);
  }
  ...
}
```



## State Pattern Example 3 - SPOP (Continued)

- Note, that in this example, the state classes specify the next state
- We could have the SPop class itself determine the state transition (the state classes now return true of false):

```
public class SPop {
  private SPopState state = new Start();
  public void user(String userName) {
    state.user(userName);
    state = new HaveUserName(userName);
  }
  public void pass(String password) {
    if (state.pass(password))
      state = new Authorized();
    else
      state = new Start();
  }
}
```

## State Pattern Example 3 - SPOP (Continued)

- Multiple instances of SPop could share state objects if the state objects have no required instance variables or the state objects store their instance variables elsewhere
- Such sharing of objects is an example of the Flyweight Pattern
- How can the state object store its state elsewhere?
  - ⇨ Have the Context store this data and pass it to the state object (a push model)
  - ⇨ Have the Context store this data and have the state object retrieve it when needed ( a pull model)



## State Pattern Example 3 - SPOP (Continued)

- Here's an example of the Context storing the state and passing it to the state objects:

```
public class SPop {
  private SPopState state = new Start();
  String userName;
  String password;

  public void user(String newName) {
    this.userName = newName;
    state.user(newName);
  }

  public void pass(String password) {
    state.pass(userName, password);
  }
  ...
}
```

## State Pattern Example 3 - SPOP (Continued)

- Here the Context stores the state and the state objects retrieve it:

```
public class SPop {
  private SPopState state = new Start();
  String userName;
  String password;

  public String getUserName() {return userName;}

  public String getPassword() {return password;}

  public void user(String newName) {
    this.userName = newName ;
    state.user(this);
  }
  ...
}
```



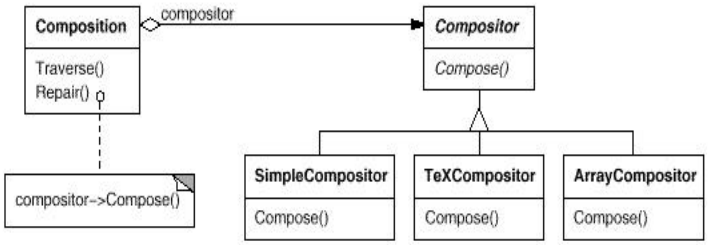
## State Pattern Example 3 - SPOP (Continued)

- And here is how the HaveUserName state object retrieves the state in its user() method:

```
public class HaveUserName extends SPopState {

  public SPopState user(SPop mailServer) {
    String userName = mailServer.getUserName();
    ...
  }
  ...
}
```

## The Strategy Pattern

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





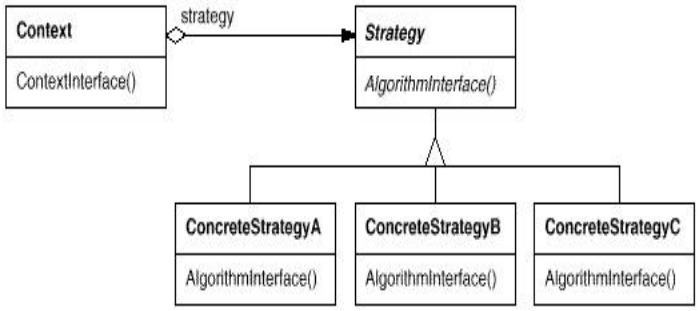

## The Strategy Pattern

- Applicability

  Use the Strategy pattern whenever:
  - ➡ Many related classes differ only in their behavior
  - ➡ You need different variants of an algorithm
  - ➡ An algorithm uses data that clients shouldn't know about. Use the Strategy pattern to avoid exposing complex, algorithm-specific data structures.
  - ➡ A class defines many behaviors, and these appear as multiple conditional statements in its operations. Instead of many conditionals, move related conditional branches into their own Strategy class.

## The Strategy Pattern

- Structure



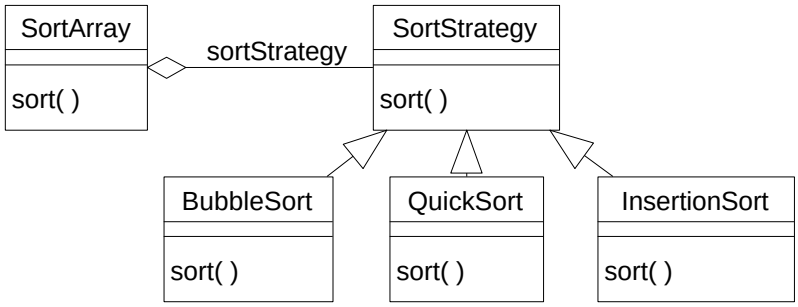



## The Strategy Pattern

- Consequences
  - ⇨ Benefits
    - ➟ Provides an alternative to subclassing the Context class to get a variety of algorithms or behaviors
    - ➟ Eliminates large conditional statements
    - ➟ Provides a choice of implementations for the same behavior
  - ⇨ Liabilities
    - ➟ Increases the number of objects
    - ➟ All algorithms must use the same Strategy interface

## Strategy Pattern Example 1

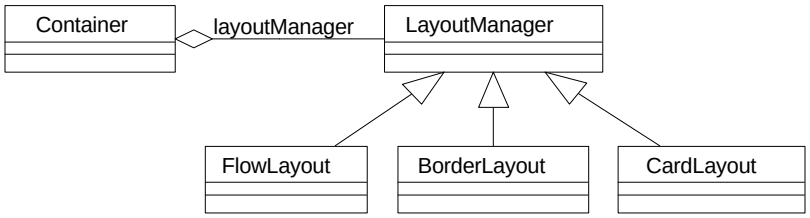
- Situation: A class wants to decide at run-time what algorithm it should use to sort an array. Many different sort algorithms are already available.
- Solution: Encapsulate the different sort algorithms using the Strategy pattern!






## Strategy Pattern Example 2

- Situation: A GUI container object wants to decide at run-time what strategy it should use to layout the GUI components it contains. Many different layout strategies are already available.
- Solution: Encapsulate the different layout strategies using the Strategy pattern!
- Hey! This is what the Java AWT does with its LayoutManagers!



## Strategy Pattern Example 2 (Continued)

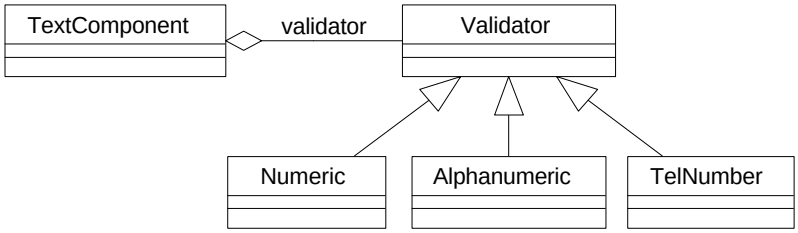
- Some client code:

```
Frame f = new Frame();
f.setLayout(new FlowLayout());
f.add(new Button("Press"));
```



## Strategy Pattern Example 3

- Situation: A GUI text component object wants to decide at run-time what strategy it should use to validate user input. Many different validation strategies are possible: numeric fields, alphanumeric fields, telephone-number fields, etc.
- Solution: Encapsulate the different input validation strategies using the Strategy pattern!



## Strategy Pattern Example 3 (Continued)

- This is the technique used by the Java Swing GUI text components. Every text component has a reference to a document model which provides the required user input validation strategy.



## The Null Object Pattern

- Sometimes the Context may not want to use the strategy provided by its contained Strategy object. That is, the Context wants a "do-nothing" strategy.
- One way to do this is to have the Context assign a null reference to its contained Strategy object. In this case, the Context must always check for this null value:

```
if (strategy != null)
   strategy.doOperation();
```

## The Null Object Pattern

- Another way to accomplish this is to actually have a “do-nothing” strategy class which implements all the required operations of a Strategy object, but these operations do nothing. Now clients do not have to distinguish between strategy objects which actually do something useful and those that do nothing.
- Using a “do-nothing” object for this purpose is known as the *Null Object Pattern*



## The Strategy Pattern

- Note the similarities between the State and Strategy patterns! The difference is one of intent.
  - ⇒ A State object encapsulates a state-dependent behavior (and possibly state transitions)
  - ⇒ A Strategy object encapsulates an algorithm
- And they are both examples of Composition with Delegation!