Template Method [GoF]

Intent

Provide a skeleton of an algorithm in a method, deferring some steps to subclasses.

Motivation

Suppose you have to write several `Buffer` classes all supporting the methods

- `public void put(Object o) throws InterrruptedException`
- `public Object get() throws InterrruptedException`

One or more producer threads put objects into an instance of `Buffer` provided that it is not full; one or more consumer threads get objects from the same instance of `Buffer` provided that it is not empty.

Writing to a full `Buffer` instance blocks the producer; reading from an empty `Buffer` instance blocks the consumer.

The sketch of a variant of a `Buffer` class might look like:


```
// Buffer variant.
public class BoundedBuffer {
   private Object[] buf; int putPtr = 0, getPtr = 0;
   private int usedSlots = 0;

   public BoundedBuffer (int capacity) throws
      IllegalArgumentException
   {
      if (capacity <= 0) throw new IllegalArgumentException();
      buf = new Object[capacity];
   }

   public synchronized void put(Object o) throws InterruptedE.{
   /*1*/ while (_usedSlots == _buf.length) {
            wait();
         }
   /*2*/ buf[putPtr] = obj; putPtr = (putPtr + 1)%buf.length;
   /*3*/ if (usedSlots++ == 0) {
            notifyAll();
         }
   }
   ... }
```


The `get` method of above class `BoundedBuffer` is analogous:

```
// In class BoundedBuffer:
   public synchronized Object get() throws InterruptedEx. {
   /*1*/ while (usedSlots == 0) { wait(); }
   /*2*/ Object x = buf[outPtr]; buf[outPtr] = null;
         outPtr = (outPtr + 1) % buf.length;
   /*3*/ if (usedSlots-- == capacity) {
            notifyAll();
         }
         return x;
   }
```

Analyzing the code of the methods `put` and `get` shows that their actions depend on the state of the buffer. The buffer is in one of the following states:

State	***Condition***	***put***	***take***
`full`	`usedSlots == capacity`	`no`	`yes`
`partial`	`0 < usedSlots < capacity`	`yes`	`yes`
`empty`	`usedSlots == 0`	yes	no

So, for method `put` for example, the following *state-dependent actions* are carried out:

```
// pseudo code:
public synchronized void put(Object o) throws InterruptedEx. {
/*1*/ wait while full;
/*2*/ insert object into buf;
/*3*/ notifyAll if buf was empty;
}
```

This kind of sequence of applies for many kind of implementations of buffer variants. Consider for example a one place buffer:

```
// pseudo code for a one place buffer:
public synchronized void put(Object o) throws InterruptedEx. {
/*1*/ wait while full;
/*2*/ insert object into one place buf;
/*3*/ notifyAll if buf was empty
}
```

The comparison of the pseudo-code section above yields:

- `/*1*/` part `wait while full` seems to be equal
- `/*2*/` insertion part is subject to the underlaying data structure
- `/*3*/` notification part depends on the state structure of the buffer variant

The similarities for method `put` can be described as follows:

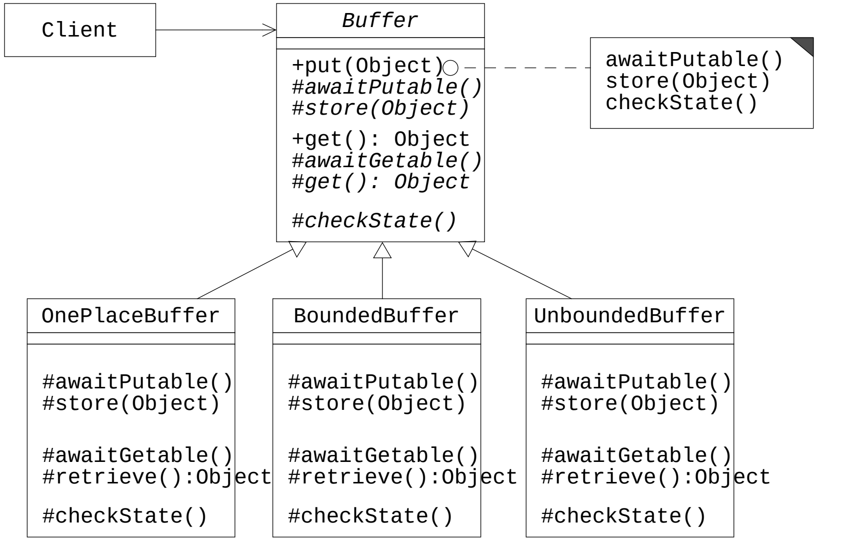
```
// pseudo code:
public synchronized void put(Object o) throws InterruptedEx.{
   common_wait_while_full();
   specialized_insertion(o);
   specialized_notification();
}
protected abstract void specialized_insertion(Object o);
protected abstract void specialized_notification();
```

Similar things can be said for the `get` method. It seems that each of the methods can be divided into a sequence of more *primitive* methods. One of them seems to be implementable for all kind of buffer (`common_wait_while_full`), while others need to be specialized.

The following class diagram can now be derived from the above discussion. The diagram shows that public method `put` is composed of more primitive methods.

Method `awaitPutable` is private and fully implemented, while methods `store` and `checkState` are protected and abstract.

Methods `put` and `get` are called *template methods* since they define an algorithm in terms of more primitive, abstract and/or concrete methods. Subclasses then override the abstract primitive methods.

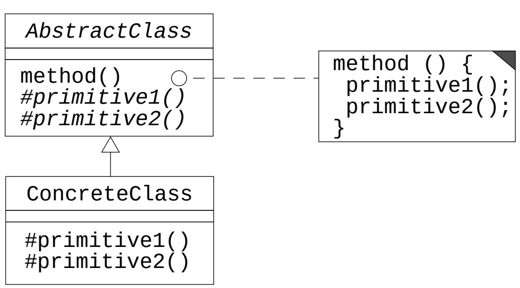


Applicability

The Template Method pattern should be used:

- to implement invariant parts of an algorithm once, and to leave it to subclasses to implement parts of the algorithm that can vary
- when common behavior among subclasses should be factored and localized in a common class to avoid code duplication
- to control subclass extensions

Structure



Participants

- `AbstractClass`:
  - defines abstract/concrete primitive methods that subclasses override
  - implements a template method defining the skeleton of an algorithm
- `Concrete Class`:
  - implements the primitive methods

Collaborations

- `ConreteClass` relies on `AbstractClass` to implement primitive methods
- Clients preferably bind to the `AbstractClass` type which they may receive via factory method from, say, a factory.

Consequences

- Template methods are a fundamental technique for code reuse, for example, in class libraries.
- Template methods lead to an inverted control structure that's sometimes referred to as the "Hollywood principle," that is, "Don't call us, we call you".
- Template methods are equally well applicable in frameworks: They invoke so-called *hook methods*, which provide default behavior which subclasses can extend if necessary.
- It's important for template methods to specify which methods are hooks (*may* be overridden) and which are abstract operations (*must* be overridden).

Implementation

- **Access control:** Primitive methods should be declared as protected. This ensures that they are only called by the template method.
- **Minimizing primitive methods:** Minimize the number of primitive methods that a subclass must override to implement the algorithm.
- **Naming convention:** You can identify the methods that should be overridden by adding a prefix to their names.

Sample Code

The following code example shows a class hierarchy of `Buffer` classes. We start with the abstract class `Buffer`:

```
public abstract class Buffer {
   protected static final int EMPTY = 0, FULL  = 1;
   protected int state = EMPTY;

   public void init(int size)// used for buffer size initial.
      throws IllegalArgumentException {}

   public final synchronized void put(Object x) throws Int.Ex.
   {
      awaitPutable();
      store(x);
      checkState();
   }

   public final synchronized Object get() throws Interr.Ex. {
      awaitGetable();
      Object x = retrieve();
      checkState();
      return x;
   }
   protected abstract void store(Object x) throws Interr.Ex.;
   protected abstract Object retrieve() throws Interr.Ex.;
```


Concrete buffer classes subclass class `Buffer`. For example, class `BoundedBuffer`:

```
public class BoundedBuffer extends Buffer
{  private static final int MIDDLE = 2;
   protected Object[] buffer;
   protected int putPtr = 0;
   protected int getPtr = 0;
   protected int usedSlots = 0;

   public void init(int capacity)
      throws IllegalArgumentException {
      if (capacity <= 0)
         throw new IllegalArgumentException();
      buffer = new Object[capacity];
   }

   protected synchronized void store(Object x) {
      buffer[putPtr] = x;
      putPtr = (putPtr + 1) % buffer.length;
      usedSlots++;
   }
```



```
   // Buffer class continued...
   private final synchronized void awaitPutable()
      throws InterruptedException
   {
      while (state == FULL) {
         try {
            wait();
         } catch (InterruptedException ex) { throw ex; }
      }
   }
   private final synchronized void awaitGetable()
      throws InterruptedException
   {  while (state == EMPTY) {
         try {
            wait();
         } catch (InterruptedException ex) { throw ex;}
      }
   }
   protected abstract void checkState();
}
```



```
   protected synchronized Object retrieve() {
      Object x = buffer[getPtr];
      getPtr = (getPtr + 1) % buffer.length;
      usedSlots--;
      return x;
   }

   protected synchronized void checkState() {
      int oldState = state;

      if      (usedSlots == 0)              state = EMPTY;
      else if (usedSlots == buffer.length)  state = FULL;
      else                                  state = MIDDLE;

      // Notify when leaving BOTTOM or TOP states.
      if (state != oldState &&
         (oldState == EMPTY || oldState == FULL))
         notifyAll();
   }
}
```

Related Patterns

Factory Methods are often called by template methods.

Strategy: Template methods use inheritance to vary part of an algorithm. Strategies use delegation to vary the entire algorithm.