4 Design patterns

Main concepts to be covered

- Why design patterns matters
- Classification of patterns
- Some common patterns
  - Composite
  - Decorator
  - Singleton
  - Factory method
  - Observer

Why design patterns matters

- Inter-class relationships are important, and can be complex.
- Some relationships recur in different applications.
- Design patterns help clarify relationships, and promote reuse.
- Don’t reinvent the wheel!

Small and large Patterns

- Architectural patterns (large scale)
- Design patterns (medium scale)
- Idioms (small scale)

Architectural Pattern

- Fundamental structural organization template for a whole software system.
- It provides
  - a set of predefined subsystems
  - responsibilities of subsystems
  - relationships between subsystems
- Example Model View Controller

Design pattern

- Medium scale organization scheme for components of a software system.
- It provides
  - a scheme for refining components and their relationships.
  - communication rules for cooperating components.
- It is independent of programming language.
- Example Observer

Idiom

- Low level design pattern.
- Programming language specific implementation techniques.
- Example: The string copy loop idiom for the C/C++ programming language
  - `while ((*t++ = *s++) != '\0') ;`

Design pattern categories

- ***Creational patterns:*** Object creation.
  - Singleton, Factory, Abstract Factory, Factory Method, ...
- ***Structural patterns:*** Static composition.
  - Composite, Decorator, Adapter, ...
- ***Behavioral patterns:*** Dynamic object interaction.
  - Iterator, Command, State, Template Method, Strategy, ...

Design pattern description

A design pattern description consists of
- *Pattern name*.
- *Category:*
  - Creational, Structural, or behavioral.
- *Intent:*
  - The problem addressed by it.
- *Structure:*
  - Class diagram showing participants and relationships.
- *Participants:*
  - A list of participating classes or objects and their collaboration.
- *Applicability:*
  - Situations in which it is useful.
- *Its consequences:*
  - Results, trade-offs.

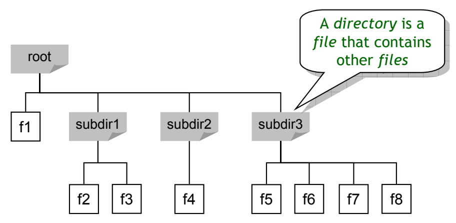
Composite

- Composite defines a part-whole relationship between objects in a tree hierarchy.
- Simple objects and composite objects can be treated *uniformly* by clients
  - uniformly with respect to their *common interface*.

Composite (2)

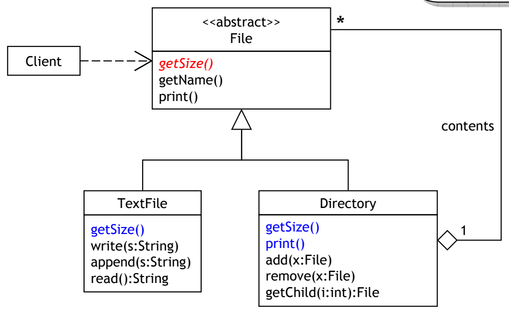
Example instances:
- `Component, Container, JPanel, JButton,...`
- Hierarchical file systems have two kinds of files
  - "Ordinary" files (Leaf) contain data.
  - Directories (Composite) contain files.

An instance of Composite: Hierarchical file systems

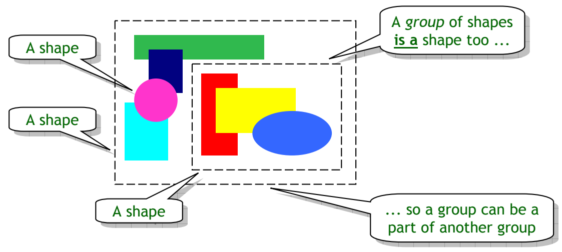


A file system

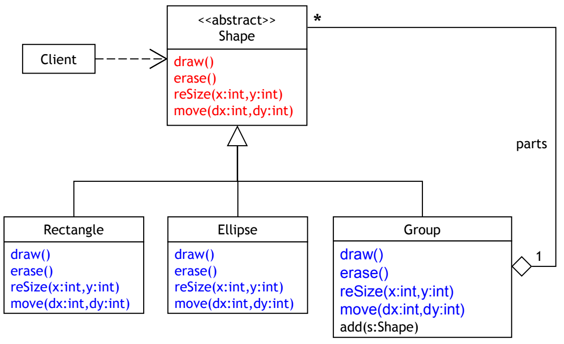
Explore the **file_system** project



Another instance of Composite: Hierarchical geometrical shapes



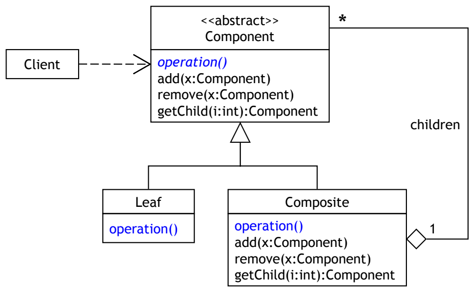
Geometrical shapes



General Composite Pattern

- Participating classes:
  - Component (abstract class)
    - declares common operations and default behavior.
  - Leaf ("base case")
    - implements behavior for the primitive elements in the composition.
  - Composite ("recursion")
    - manages child components.
  - Client
    - manipulates objects in the composition via the Component interface.

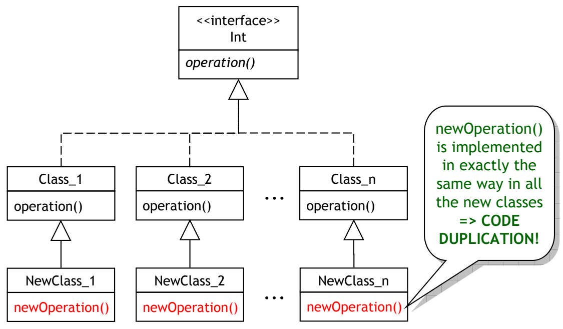
General Composite Pattern



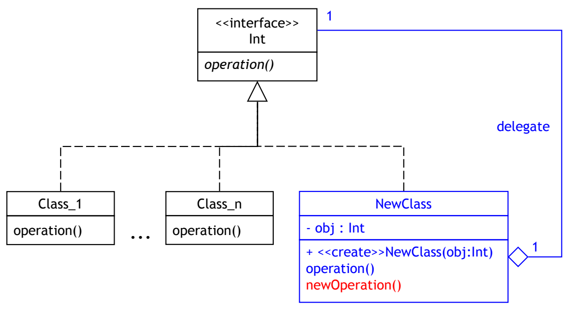
Decorator

- Augments the functionality of an object.
- Decorator object wraps another object.
  - The Decorator object has a similar interface.
  - Calls are relayed to the wrapped object …
  - … but the Decorator can interpolate additional actions.
- Example: `java.io.BufferedReader`
  - Wraps and augments an unbuffered **`Reader`** object.

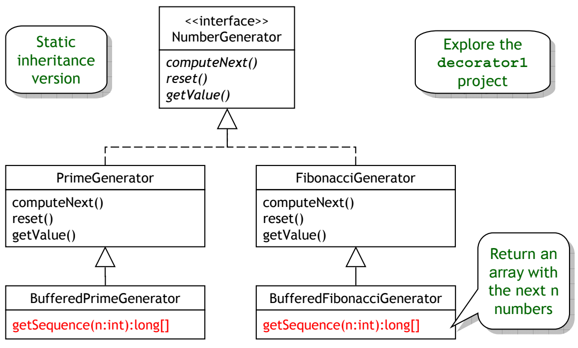
Extension by inheritance



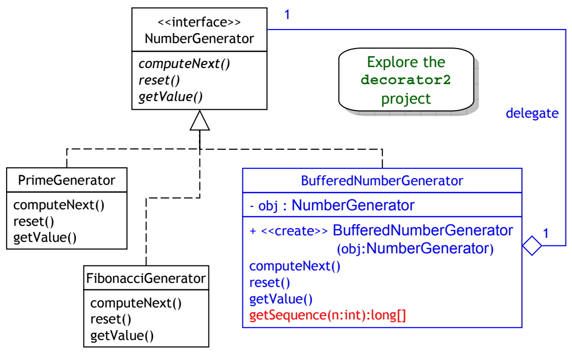
Extension using Decorator pattern



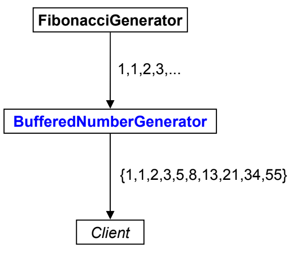
Example: Number generator



Decorated NumberGenerator



Using the BufferedNumberGenerator



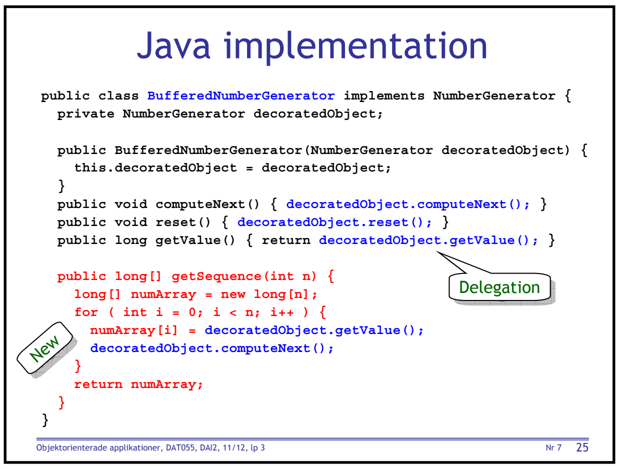
Using the BufferedNumberGenerator

```
BufferedNumberGenerator bp =
    new BufferedNumberGenerator(new PrimeGenerator());

BufferedNumberGenerator bf =
    new BufferedNumberGenerator(new FibonacciGenerator());

...
bp.computeNext();
long x = bp.getvalue();
...
bp.reset();
long[] array = bp.getSequence(10);
               {2,3,5,7,11,13,17,19,23,29}
```

NumberGenerator methods work for buffered generators too



Java implementation

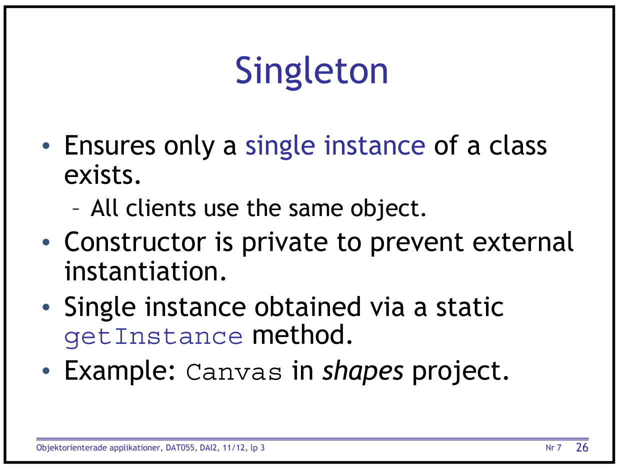
```
public class BufferedNumberGenerator implements NumberGenerator {
  private NumberGenerator decoratedObject;

  public BufferedNumberGenerator(NumberGenerator decoratedObject) {
    this.decoratedObject = decoratedObject;
  }
  public void computeNext() { decoratedObject.computeNext(); }
  public void reset() { decoratedObject.reset(); }
  public long getValue() { return decoratedObject.getValue(); }

  public long[] getSequence(int n) {
    long[] numArray = new long[n];
    for ( int i = 0; i < n; i++ ) {
      numArray[i] = decoratedObject.getValue();
      decoratedObject.computeNext();
    }
    return numArray;
  }
}
```

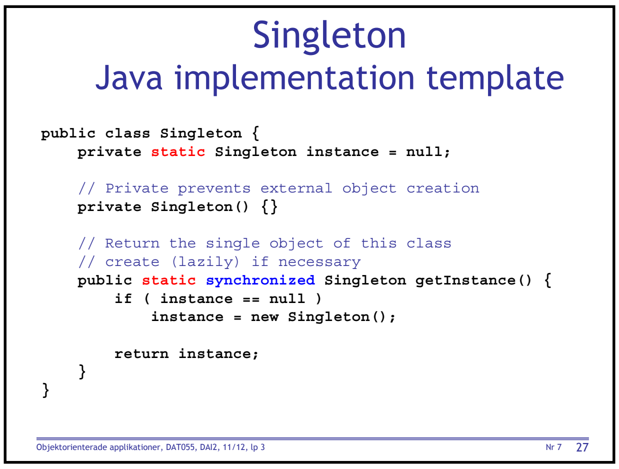
Delegation

New



Singleton

- Ensures only a single instance of a class exists.
  - All clients use the same object.
- Constructor is private to prevent external instantiation.
- Single instance obtained via a static `getInstance` method.
- Example: `Canvas` in *shapes* project.



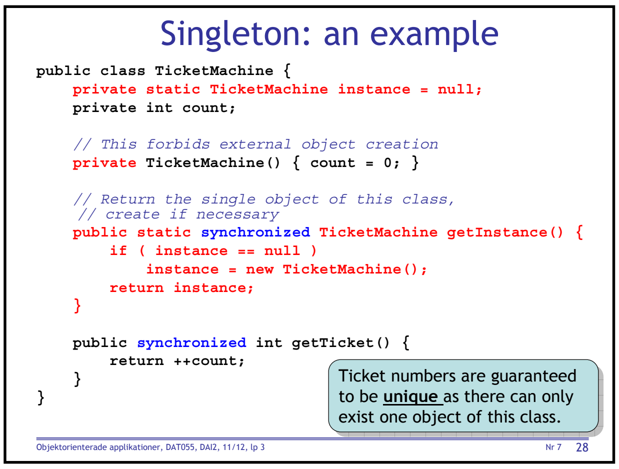
Singleton Java implementation template

```
public class Singleton {
    private static Singleton instance = null;

    // Private prevents external object creation
    private Singleton() {}

    // Return the single object of this class
    // create (lazily) if necessary
    public static synchronized Singleton getInstance() {
        if ( instance == null )
            instance = new Singleton();

        return instance;
    }
}
```



Singleton: an example

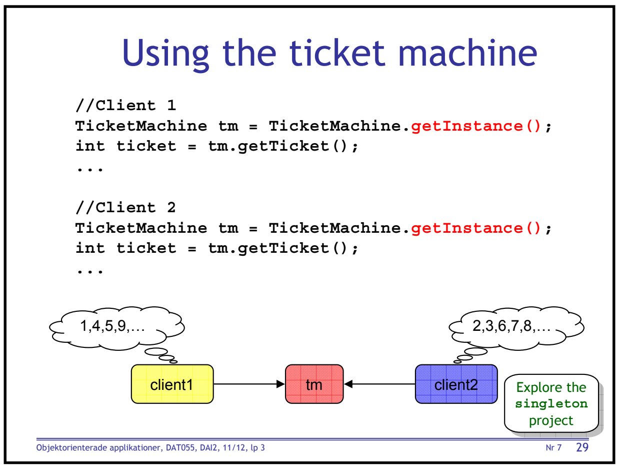
```
public class TicketMachine {
    private static TicketMachine instance = null;
    private int count;

    // This forbids external object creation
    private TicketMachine() { count = 0; }

    // Return the single object of this class,
    // create if necessary
    public static synchronized TicketMachine getInstance() {
        if ( instance == null )
            instance = new TicketMachine();
        return instance;
    }

    public synchronized int getTicket() {
        return ++count;
    }
}
```

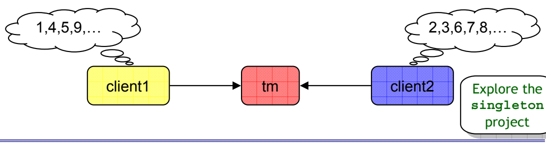
Ticket numbers are guaranteed to be **unique** as there can only exist one object of this class.



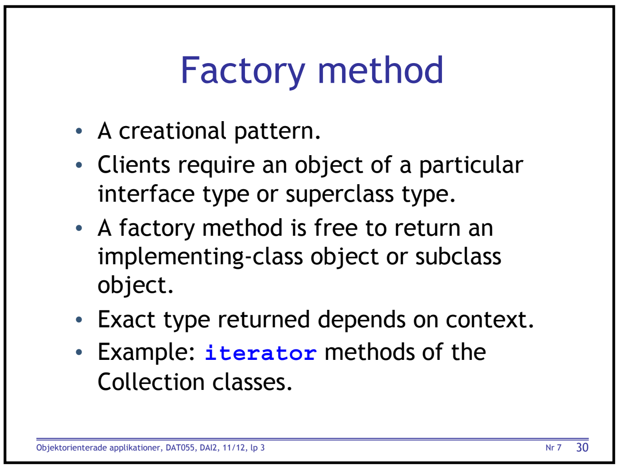
Using the ticket machine

```
//Client 1
TicketMachine tm = TicketMachine.getInstance();
int ticket = tm.getTicket();
...

//Client 2
TicketMachine tm = TicketMachine.getInstance();
int ticket = tm.getTicket();
...
```



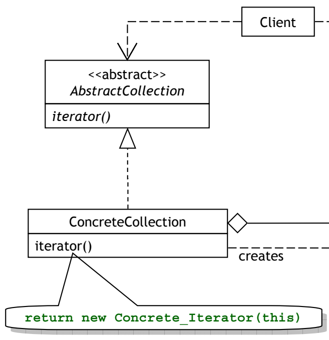
Explore the `singleton` project



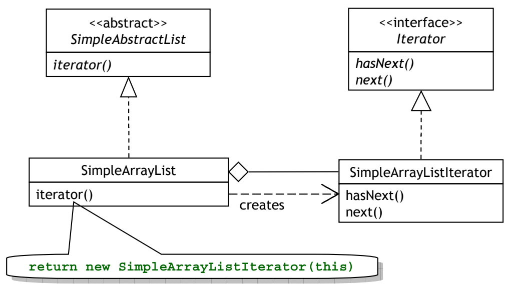
Factory method

- A creational pattern.
- Clients require an object of a particular interface type or superclass type.
- A factory method is free to return an implementing-class object or subclass object.
- Exact type returned depends on context.
- Example: `iterator` methods of the Collection classes.

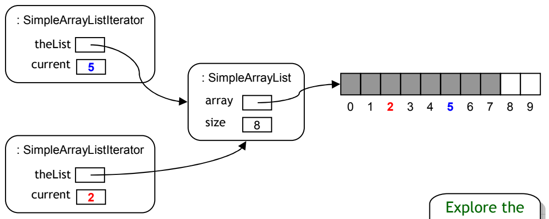
Factory method (2)



Example: `SimpleArrayList`



Example: `SimpleArrayList` (2)

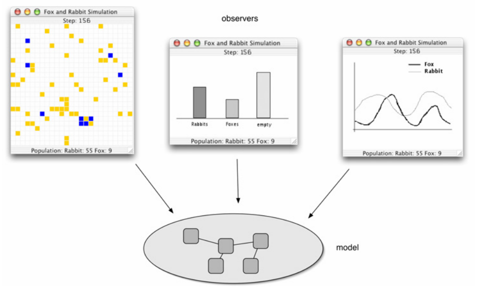


Explore the `factory` project

Observer

- Supports separation of internal model from a view of that model.
- Observer defines a one-to-many relationship between objects.
- The object-observed notifies all Observers of any state change.
- Example `SimulatorView` in the *foxes-and-rabbits project*.

Observers



Review

- Design flexible, extendible and maintainable class structures.
- Being aware of existing design patterns will help you to do this.