A Brief Overview of Design Patterns

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What is a *design pattern*?

- A *design pattern* is a description of communicating objects and classes that are customized to solve a general design problem in a particular context.

A simplistic example

- Problem: Read a sequence of employee data from a file until a particular employee ID is read.

```
f = open( 'input.data', 'rb' )
data = f.read( bytesOfData )
while data.id != IDToStop :
  store data in structure (e.g., table, tree)
  data = f.read( bytesOfData )
```

A "pattern" emerges:

```
prime the condition
while the condition is true:
  do some work
  update the condition
```

Pattern Reuse

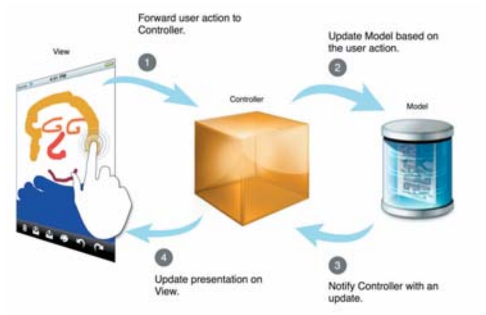
- More importantly, the pattern can be reused in many different applications
  – Accumulate a sequence of integers with a sentinel value
  – Find a maximal (minimal) value in a sequence
  – … many more

Two important facts w.r.t. DP

- Two very important pieces of information play critical role in the concepts of design patterns
  – MVC: Model-View-Control design pattern segregates the objects into three roles, *model, view*, and *control.* The pattern dates back to the days of *Smalltalk*, late 70's and early 80's. Still critically important today.
  – The publication of *Design Patterns: Elements of Reusable Object-Oriented Software*, by Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides (Addison-Wesley Professional, 1994), a.k.a. Gang of Four (GOF).

Model in MVC

- Encapsulate data and basic behaviors in *model*
- Model objects maintain
  – Application data
  – The logics that manipulate these data
- View objects
  – Respond to user actions
  – Present to the user the data from the model
- Control objects act in between model and view

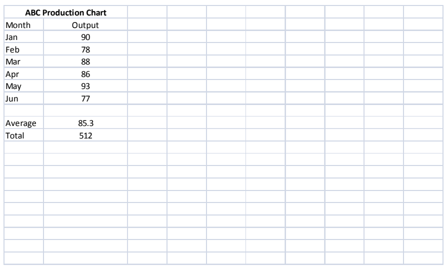

Forward user action to Controller.
1
View
Update Model based on the user action.
2
Controller
Model
4
Update presentation on View.
3
Notify Controller with an update.

The diagram is from the book by Chung (2011)

An *Excel* example

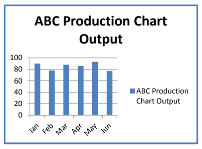
- Given an Excel spreadsheet that keeps the production output for a company in the first six months of the year, show the user in various form, compute average, or total as requested

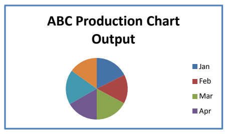
Model (The data and computation)

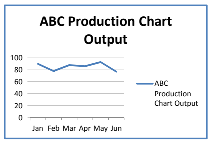


ABC Production Chart	
Month	Output
Jan	90
Feb	78
Mar	88
Apr	86
May	93
Jun	77
Average	85.3
Total	512

Views (What users may see)





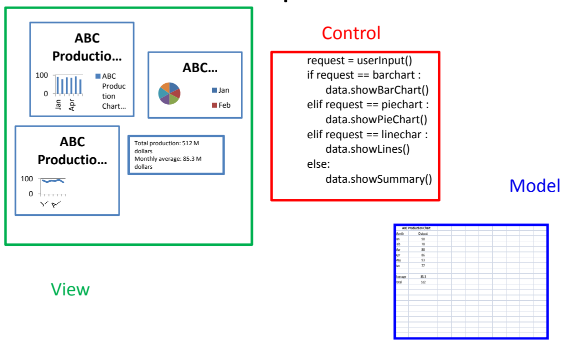


Total production: 512 M dollars
Monthly average: 85.3 M dollars

Control
(Interface between a user and the data)

```
request = userInput()
if request == barchart :
    data.showBarChart()
elif request == piechart :
    data.showPieChart()
elif request == linechar :
    data.showLines()
else:
    data.showSummary()
```

Our example of MVC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Keys to MVC

- Separation of functions among different objects (OO Design Principle 1: *low coupling*!)
- Single class (object) should have a single responsibility (OO Design Principle 2: *high cohesion*!)

Issues affecting design

- *Programming To An Interface, Not An Implementation*
  - Design should concentrate on interface (behavior), not specific implementation
- *@protocol vs. Abstract Base Class* (ABC) (in the terms of Objective-C), or *interface vs. abstract class* (in the terms of Java)
  - Contrast between @protocol (Java interface) and ABC (Java ABC)
- *Object Composition vs. Class Inheritance*
  - Composition (black-box, properties hidden), inheritance (white-box, properties visible)

Example of *behavior*

- We want to add books to a container that allows search, the details of the container is not the concern of the user (applications)

```
import bst as BookCase
#import avltree as BookCase
#import linkedlist as BookCase
myShelf = BookCase()
abook = read_from_the_user()
while abook != None:
  myShelf.add( abook )
  abook = read_from_the_user()
```

Example of interface vs. ABC

```
public interface Walkable {
   void walk();
}
```

```
public abstract class Pet implements Walkable {
   protected String name;
   public Pet(String name) {this.name = name; }
   public void walk() {System.out.println("Pet's common walk!"); }
}
```

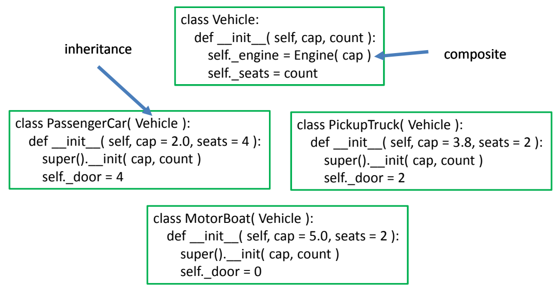
```
public class PetOwner implements Walkable {
   private String name;
   public PetOwner(String name) { this.name = name;   }
   public void walk() {
      System.out.println(this.name + " : Exercise is good for me.");
   }
}
```

```
public class Dog extends Pet implements Walkable {
     public Dog(String name) { super(name);  }
     @Override    public void walk() {
          super.walk(); // Activate the parent's method before its own
          System.out.println("Dog " + this.name + " : Pant!!! Where's my leash!?!");
     }
}
```

Applications that might use both

```
public class TestWalking {
   public static void sendWalking(Walkable walkObj) {
              walkObj.walk();
   }
   public static void main(String[] args) {
              PetOwner bob = new PetOwner("Tarzan"),
                 jane = new PetOwner("Jane");
              Pet[] ourPets = {new Dog("Spot"), new Cat("Fluffy"), new Dog("Ceaser"),
                 new Dog("Roadkill") };
              sendWalking(bob);
              sendWalking(jane);
              for (Pet p : ourPets)
                 sendWalking(p);
   }
}
```

Example of composite and inheritance



```
class Vehicle:
   def __init__( self, cap, count ):
      self._engine = Engine( cap )
      self._seats = count
```

```
class PassengerCar( Vehicle ):
   def __init__( self, cap = 2.0, seats = 4 ):
      super().__init( cap, count )
      self._door = 4
```

```
class PickupTruck( Vehicle ):
   def __init__( self, cap = 3.8, seats = 2 ):
      super().__init( cap, count )
      self._door = 2
```

```
class MotorBoat( Vehicle ):
   def __init__( self, cap = 5.0, seats = 2 ):
      super().__init( cap, count )
      self._door = 0
```

Common software design patterns

- In three general groups (23 original GOF patterns)
  - *Creational patterns*: object creation mechanisms, trying to create objects in a manner suitable to the situation.
  - *Structural patterns*: design by identifying a simple way to realize relationships between entities.
  - *Behavioral patterns*: common communication patterns between objects and realize these patterns.

Creational patterns

- **Abstract factory**: Provide an interface for creating families of related or dependent objects without specifying their concrete classes.
- **Builder**: Separate the construction of a complex object from its representation allowing the same construction process to create various representations.
- **Factory method**: Define an interface for creating an object, but let subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.
- **Prototype**: Specify the kinds of objects to create using a prototypical instance, and create new objects by copying this prototype.
- **Singleton**: Ensure a class has only one instance, and provide a global point of access to it.

Structural patterns (1)

- **Adapter** (Wrapper or Translator): Convert the interface of a class into another interface clients expect.
- **Bridge**: Decouple an abstraction from its implementation allowing the two to vary independently.
- **Composite**: Compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions of objects uniformly.
- **Decorator**: Attach additional responsibilities to an object dynamically keeping the same interface. Decorators provide a flexible alternative to subclassing for extending functionality.

Structural patterns (2)

- **Façade**: Provide a unified interface to a set of interfaces in a subsystem. Facade defines a higher-level interface that makes the subsystem easier to use.
- **Flyweight**: Use sharing to support large numbers of similar objects efficiently.
- **Proxy**: Provide a surrogate or placeholder for another object to control access to it.

Behavioral patterns (1)

- **Chain of responsibility**: Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request. Chain the receiving objects and pass the request along the chain until an object handles it.
- **Command**: Encapsulate a request as an object, thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operations.
- **Interpreter**: Given a language, define a representation for its grammar along with an interpreter that uses the representation to interpret sentences in the language.
- **Iterator**: Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.

Behavioral patterns (2)

- **Mediator**: Define an object that encapsulates how a set of objects interact. Mediator promotes loose coupling by keeping objects from referring to each other explicitly, and it lets you vary their interaction independently.
- **Memento**: Without violating encapsulation, capture and externalize an object's internal state allowing the object to be restored to this state later.
- **Observer** (or Publish/subscribe): Define a one-to-many dependency between objects where a state change in one object results in all its dependents being notified and updated automatically.
- **State**: Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.

Behavioral patterns (3)

- **Strategy**: Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it.
- **Template method**: Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template method lets subclasses redefine certain steps of an algorithm without changing the algorithm's structure.
- **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.

An *iterator* example

- Iterator is almost a universal structure (pattern!) needed by all objects
- For example, your management asked your team to write a collection of programs to examine the performance of various search algorithms, using linear search, binary search, binary search trees, AVL trees, and hash table.
- Each of these structures needs an iterator.
- See the code example in code/iterator

References

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- Gamma, E., Helm, R., Johnson, R., & Vlissides, J., (1994), *Design Patterns: Elements of Reusable Object-Oriented Software*, Addison-Wesley, Reading, MA.
- Wikipedia: *Software Design Pattern*, http://en.wikipedia.org/wiki/Software_design_pa ttern