CS 326
Design Patterns

Stephen Freund

What is a Design Pattern?

- A standard solution to a common programming problem

Example 1: Encapsulation

- **Problem:** Exposed properties can be directly manipulated
  - Violations of the representation invariant
  - Dependences prevent changing the implementation
- **Solution:** Hide some components
  - Constrain ways to access the object
- **Disadvantages**:
  - Interface may not (efficiently) provide all desired operations to all clients
  - Indirection may reduce performance

Example 2: Inheritance

- **Problem:** Repetition in implementations
  - Similar abstractions have similar components
- **Solution:** Inherit default members from a superclass
  - Select an implementation via run-time dispatching
- **Disadvantages**:
  - Code for a class is spread out, and thus less understandable
  - Hard to design and specify a superclass ahead of time
  - Run-time dispatching introduces overhead

Example 3: Iteration

- **Problem:** To access all members of a collection, need a specialized traversal for each data structure
  - Introduces undesirable dependences
  - Does not generalize to other collections
- **Solution:**
  - The implementation provides traversal abstraction, does bookkeeping
  - Results are communicated to clients via a standard interface (eg: Sequence methods)
- **Disadvantages:**
  - Iteration order fixed by the implementation and not under the control of the client

Example 4: Generics

- **Problem:**
  - Well-designed data structures only hold one type of object
- **Solution:**
  - Programming language checks for errors in contents
  - Set<Int> instead of just Set
- **Disadvantages:**
  - More verbose types
  - Sometimes less understandable error messages

Other Examples

- Reuse implementation without subtyping
- Reuse implementation, but change interface
- Permit a class to be instantiated only once
- Constructor that might return an existing object
- Constructor that might return a subclass object
- Combine behaviors without compile-time **extends** clauses

- You could come up with a solution to all of these on your own, but why reinvent the wheel???

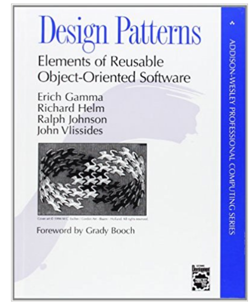
Design Pattern in More Detail

- A standard solution to a common programming problem
  - A design or implementation structure that achieves a particular purpose
  - A high-level programming idiom
- A technique for making code more flexible
  - Reduce coupling among program components
- Shorthand for describing software design
  - connections among components, heap structure, ...
- Vocabulary for communication and documentation

When To Use A Design Pattern

- Rule #1: Delay to avoid over-thinking
  - Get something basic and concrete working first
  - Improve or generalize it once you understand it
- Design patterns can increase / decrease understandability
  - Improves modularity and flexibility, separates concerns, eases description
  - But usually adds indirection, increases code size
- If you encounter a design problem, consider design patterns that address that problem

Canonical Reference



- aka: "Gang Of Four" Book

Three Kinds Of Patterns

- Creational patterns
  - constructing objects
- Structural patterns
  - combining objects, controlling heap layout
- Behavioral patterns
  - communicating among objects, affecting object semantics

Creational Patterns

- Initializers are inflexible
  - Can't return a subtype of class they belong to
  - Create new object, and never re-use existing one
- Factory Patterns
  - ADT creators that are not Swift init()s
- Sharing Patterns:
  - Reuse objects to save space or share common state

Factories: Changing Implementations

- Supertypes support multiple implementations
  - `protocol Matrix { ... }`
  - `class SparseMatrix : Matrix { ... }`
  - `class DenseMatrix : Matrix { ... }`
- Clients use the supertype (Matrix) but still create objects:
  - `let m : Matrix = SparseMatrix()` or
  - `let m : Matrix = DenseMatrix()` or …
- Switching implementations requires changing code

A Factory

```
class MatrixFactory {
  public static func createMatrix() -> Matrix {
    ...
    return SparseMatrix()
  }
}
```

- Clients call **`MatrixFactory.createMatrix()`** instead of a particular constructor

+ To switch implementation, change only one place
+ **`createMatrix()`** can do arbitrary computations to decide what kind of matrix to make

Example: Bicycle race

```
class Race {
  public init() {
    let bike1 = Bicycle()
    let bike2 = Bicycle()
    …
  }
  …
}
```

```
class TourDeFrance : Race {
  public init() {
    let bike1 = RoadBicycle()
    let bike2 = RoadBicycle()
    …
  }
  …
}
```

```
class Cyclocross : Race {
  public init() {
    let bike1 = MountainBicycle()
    let bike2 = MountainBicycle()
    …
  }
  …
}
```

Factory Method for Bicycles

```
class Race {
  func createBicycle() -> Bicycle {
    Bicycle()
  }
  init() {
    let bike1 =
     createBicycle()
    let bike2 =
     createBicycle()
    …
  }
  …
}
```

```
class TourDeFrance : Race {
  func createBicycle() -> Bicycle {
    RoadBicycle()
  }
  …
}

class Cyclocross : Race {
  func createBicycle() -> Bicycle {
    MountainBicycle()
  }
  …
}
```

Factory Object for Bicycles

```
class BicycleFactory {
  func createBicycle() -> Bicycle { ... }
  func createWheel() -> Wheel { ... }
  func createFrame() -> Frame { ... }
}

class RoadBicycleFactory: BicycleFactory {
  override func createBicycle() -> Bicycle {
    RoadBicycle()
  }
}

class MoutainBicycleFactory: BicycleFactory {
  override func createBicycle() -> Bicycle {
    MoutainBicycle()
  }
}
```

Passing Factory Objects Around

```
class Race {
  init(factory : BicycleFactory) {
    let bike1 = factory.createBicycle()
    let bike2 = factory.createBicycle()
    …
  }
}

class TourDeFrance : Race {
  init() { super.init(factory: RoadBicycleFactory()) }
}

class Cyclocross: Race {
  init() { super.init(factory: MountainBikFactory()) }
}
```

Separate Control of Bicycles / Races

```
class Race {
  init(factory : BicycleFactory) {
    let bike1 = factory.createBicycle()
    let bike2 = factory.createBicycle()
    …
  }
}

class TourDeFrance : Race {
  init(factory : BicycleFactory) {
    super.init(factory: factory)
  }
  init() { super.init(factory: RoadBicycleFactory()) }
}

let race = TourDeFrance(factory: unicycleFactory)
```

External Dependency Injection

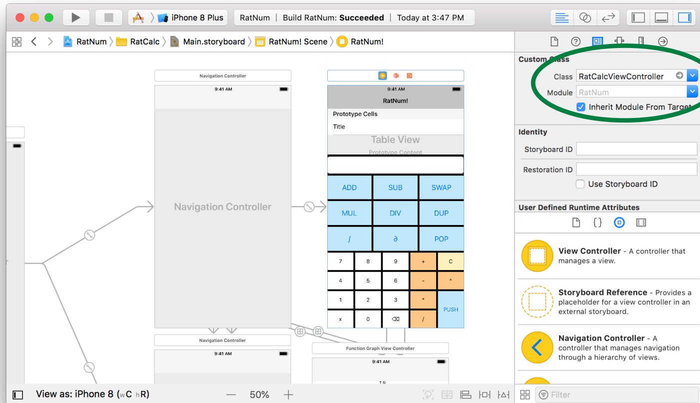
- Java Example:
  - `BicycleFactory f = new UnicycleFactory();`
  - `Race r = new TourDeFrance(f);`
- With external dependency injection:
  - `BicycleFactory f = ((BicycleFactory) DependencyManager.get("BicycleFactory"));`
  - `Race r = new TourDeFrance(f);`
- Plus an external file:

```
<service-point id="BicycleFactory">
  <invoke-factory>
    <construct class="Bicycle">
      <service>Tricycle</service>
    </construct>
  </invoke-factory>
</service-point>
```

+ Change the factory without recompiling
- External file is essential part of program

External Dependency Injection

- Interface Builder and Storyboards…



Factories: Summary

- **Problem**: Want more flexible abstractions for what class to instantiate.
- **Factory method**
  - Call method that can do any computation and return any subtype
- **Factory object**
  - Bundles factory methods for a family of types
  - Can store factory object, pass to constructors, etc.
- **Dependency Injection**
  - Put choice of subclass in a file to avoid source-code changes or even recompiling when decision changes

Design Patterns for Sharing

- **Problem:** Swift initializers always return a new object, never a pre-existing object
- **Singleton**: only one object exists at runtime
  - Factory method returns the same object every time
- **Interning**: only one object with a particular (abstract) value exists at run time
  - Factory method returns an existing object, not a new one

Singleton

- Only one object of the given type exists
- Good for unique, shared resources
  - `UserDefaults.standard`
  - `DispatchQueue.main`
  - `UIApplication.sharedApplication()`
  - Logger for diagnostic messages
- Better than lots of global properties
  - logically group related values
  - Can use initializer / factory to customize
  - eg: Internationalization: messages in a particular language

Creating Singletons

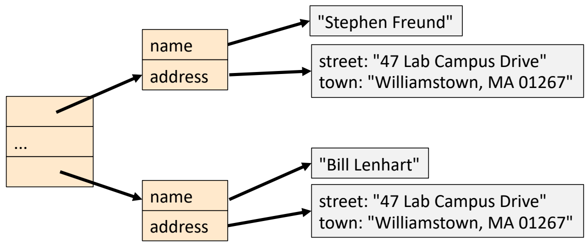
- In Swift class:
  - public constant property to hold singleton object
  - private initializer

```
class Logger {
  static public let instance = Logger()
  private init() { ... }
}
```

- In client:
  - Refer to the single instance of the Singleton class
  - `Logger.instance.print("button clicked")`

Interning pattern

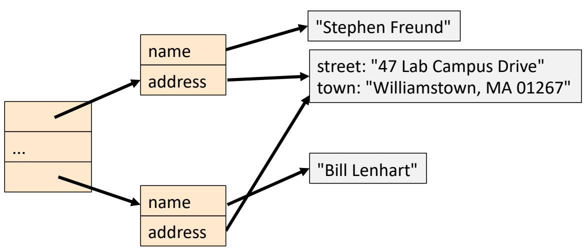
- Reuse existing objects instead of creating new ones




```
class Address : Hashable {
  let street : String
  let town : String
  ...
}
```

Interning pattern

- Reuse existing objects instead of creating new ones



- Less space
- objects can be compared with === instead of ==
- Sensible only for immutable objects

Simple Interning Mechanism

- Maintain a collection of all objects
- If an object already appears, return that instead

```
var interned = Set<Address>()

func intern(_ n : Address) -> Address {
  // inserts if not present, returns elem == n in set.
  let (_, memberAfterInsert) = interned.insert(n)
  return memberAfterInsert
}
```

- Create the object, but perhaps discard it and return another when interning.

java.lang.Boolean and Interning

```
public class Boolean {
  private final boolean value;

  // construct a new Boolean value
  public Boolean(boolean value) {
    this.value = value;
  }

  // Singletons for true and false
  public static Boolean FALSE = new Boolean(false);
  public static Boolean TRUE = new Boolean(true);

  // factory method that uses interning
  public static Boolean valueOf(boolean value) {
    return value ? TRUE : FALSE;
  }
}
```

Should have never been made public

```
Boolean b = Boolean.valueOf(true);
```

vs

```
Boolean b = new Boolean(true);
```