CS 326
Object-Oriented Design

Stephen Freund

1

Swift Extensions

- Extend existing data structure, even if no access to source

Limitations
- only sees public members of original type
- cannot override existing methods
- only computed properties can be added

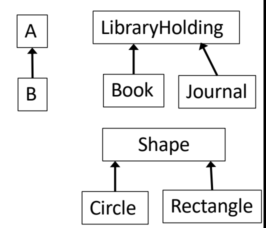
```
extension CGPoint {
  func distance(to point: CGPoint) -> CGFloat {
    return hypot(point.x - x, point.y - y)
  }
}

 ...
 let distance = pt.distance(to: other)
```

Extensions

- Primary Use: small, self-contained helper methods

- Use sparingly
- Can obfuscate code
- Don't use in place of good oo design
- When in doubt, don't!

Subtyping



- Sometimes “every B is an A”

- “B is a subtype of A” means:
  Every object that satisfies the rules for a B also satisfies the rules for an A

- Code written using A's specification operates correctly even if given a B object.
  - Plus: clarify design, share tests, (sometimes) share code

Substitutivity

- Subtypes are **substitutable** for supertypes
  - Instances of subtype won't surprise client by:
    - failing to satisfy the supertype's specification
    - having more expectations than the supertype's specification
- B is a **true subtype** of A if B has a stronger specification than A
  - This is not the same as a Swift (C++/Java/...) subtype
  - Subtypes that are not true subtypes are confusing and dangerous

True Subtypes For Classes

```
class A { ... }
class B : A { ... }
```

- If a B object is used in place of an A object, then the result should be consistent with having just used an A object.
- B can:
  - Add properties and methods (that preserve invariants)
  - Override a method with one having a stronger (or equal) spec
- B cannot:
  - Remove properties or method
  - Override a method with one having a weaker spec

Stronger Method Specifications

- Promise More: Stronger Post
  - Returns clause harder to satisfy
  - Fewer objects in modifies clause
  - Effects clause harder to satisfy
- Ask less of client: Weaker Pre
  - Requires clause easier to satisfy

```
class Array {

  /// -Returns: index of
  /// key in items
  func index(of key: Int)
}

class StrongerArray : Array {

  /// -Returns: index of
  /// first occurrence of in
  /// key items
  func index(of key: Int)
```

Stronger Method Specifications

- Promise More: Stronger Post
  - Returns clause harder to satisfy
  - Fewer objects in modifies clause
  - Effects clause harder to satisfy
- Ask less of client: Weaker Pre
  - Requires clause easier to satisfy

```
class Array {

  /// -Modifies: self, other
  func append(other: Array)
}

class StrongerArray : Array {

  /// -Modifies: self
  func append(other: Array)
```

Stronger Method Specifications

- Promise More: Stronger Post
  - Returns clause harder to satisfy
  - Fewer objects in modifies clause
  - Effects clause harder to satisfy
- Ask less of client: Weaker Pre
  - Requires clause easier to satisfy

```
class Point {

  /// -Effects:
  /// self.x != old(self.x)
  func move()
}

class StrongerPoint : Point {

  /// -Effects:
  /// self.x > old(self.x)
  func append(other: Array)
```

Stronger Method Specifications

- Promise More: Stronger Post
  - Returns clause harder to satisfy
  - Fewer objects in modifies clause
  - Effects clause harder to satisfy
- Ask less of client: Weaker Pre
  - Requires clause easier to satisfy

```
class Array {

  /// -Requires:
  /// self.items is sorted
  func index(of key: Int)
}

class StrongerArray : Array {

  /// -Requires:
  /// true
  func index(of key: Int)
```

Swift Subtyping

- Swift subtypes are declared:
  - **`class A : B { }`**
  - **`class A : P { }`**
  - **`class A : B, P1, P2 { }`**
  - **`protocol P : P2 { }`**
- But are these **true subtypes? Why? Why Not?**

Swift Subtyping Guarantees

- A variable's run-time type is a Swift subtype of its static (declared or inferred) type

```
class B : A
```

  - `let a: A = B()     // OK`
  - `let b: B = A()     // compile-time error`
  - `var b = B()`
    `b = A()            // compile-time error`
- Corollaries:
  - Objects always have implementations of the methods specified by their static type
  - If all subtypes are true subtypes, then all objects meet the specification of their static type

Inheritance

```
class Product {
  private let name : String
  private let description : String
  private let unitPrice : Int

  public func price() -> Int {
    return unitPrice
  }

  ...

}
```

Inheritance

```
class SaleProduct {
  private let name : String
  private let description : String
  private let unitPrice : Int

  private let discount : Double

  public func price() -> Int {
    return Int(unitPrice * discount)
  }

  ...

}
```

Inheritance

```
class SaleProduct : Product {

  private let discount : Double

  override public func price() -> Int {
    return Int(super.price() * discount)
  }

  ...

}
```

Inheritance

+ Avoids repeating code
+ Able to swap in new implementations as subclasses without breaking code
  – (if true subtypes)

- Unintuitive hierarchies
- Subtyping and inheritance are orthogonal concepts.

Is Every Square a Rectangle?

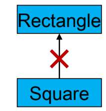
```
class MutableRectangle {
  /// Effects: fits shape to given size:
  ///          self.width = width,
  ///          self.height = height
  func set(width : Int, height : Int)
}
class MutableSquare : Rectangle {…}
```

Are any of these good specs for **`MutableSquare.set`**?

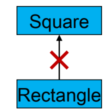
```
1. /// Requires: width == height
   /// Effects: fits shape to given size
   func set(width : Int, height : Int)
2. /// Effects: sets all edges to given size
   func set(width : Int, height : Int)
3. /// Effects:  sets self.width and self.height to width
   func set(width : Int, height : Int)
```

What's the Problem?

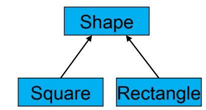
- MutableSquare is not a **true subtype** of MutableRectangle.



- MutableRectangle is not a **true subtype** of MutableSquare.



- Solutions:
  - Make them unrelated (or siblings)
  - Make them immutable (!)
    - Recovers mathematical intuition



MutableSets and Countable Sets

```
class CountingMutableSet : MutableSet {

  var addCount = 0    // should really be private...

  override func add(_ elem : Int) {
    addCount += 1
    super.add(elem)
  }

  override func addAll(_ elems : [Int]) {
    addCount += elems.count
    super.addAll(elems)
  }
}
```

Dependence on implementation

- What does this code print?

```
let c = CountingMutableSet()
c.add(1)
c.add(2)
c.addAll([3,4])
print(c.addCount)
```

- Depends on impl. of addAll in MutableSet
  - Different implementations may behave differently!
  - If MutableSet's addAll calls add, then double-counting
- Lesson: Subclassing often requires designing for extension. (eg: UIViewController)

Design for Extensibility

1. Change Spec to indicate self calls
   - Less flexibility for implementers
2. Reimplement methods to never make self calls
   - Lots of code duplication
3. Extension via Composition/Delegation

MutableSets

```
class MutableSet {
  private var elems : [Int] = []
  func add(_ elem : Int) {
    if !elems.contains(elem) {
      elems.append(elem)
    }
  }

  func addAll(_ elems : [Int]) {
    for elem in elems {
      add(elem)
    }
  }

  func contains(_ elem : Int) -> Bool {
    return elems.contains(elem)
  }

  var count : Int {
    return elems.count
  }
}
```

```
class MutableSet {
  private var elems : [Int] = []
  func add(_ elem : Int) {
    if !elems.contains(elem) {
      elems.append(elem)
    }
  }

  func addAll(_ elems : [Int]) {
    for elem in elems {
      if !elems.contains(elem) {
        elems.append(elem)
      }
    }
  }

  func contains(_ elem : Int) -> Bool {
    return elems.contains(elem)
  }

  var count : Int {
    return elems.count
  }
}
```

Composition / Delegation

Delegate

```
class CountingMutableSet {
  let delegate = MutableSet()
  var addCount = 0

  func add(_ elem : Int) {
    addCount += 1
    delegate.add(elem)
  }

  func addAll(_ elems: [Int]) {
    addCount += elems
    delegate.addAll(elems)
  }
  ...
}
```

The implementation no longer matters

DrawableGraph delegates to Graph…

Protocols

Protocol Declaration

```
protocol Set {
  func add(_ elem : Int)
  func addAll(_ other : [Int])
  func contains(_ elem : Int) -> Bool
  var count : Int { get }
}
```

Contract

Code for all protocol members

```
class MutableSet : Set { ... }

class CountingMutableSet : Set { ... }
```

Protocols

- Class/struct can implement many protocols.

```
protocol Equatable {
  static func == (lhs: Self,
                  rhs: Self) -> Bool
}
```

- **`Range`** (ie, 0..<5):
  - **`Equatable`** — ==
  - **`Indexable`** — startIndex, endIndex, index(after:), subscripting (e.g. []), index(offsetBy:)
  - **`Sequence`** — makeIterator (thus supports **`for in`**)
  - **`Collection`** — basically Indexable & Sequence & Equatable & ...
  - ...

Protocols in Foundation Library

- Array also a Collection and Sequence
- Dictionary is also a Collection and Sequence
- Set is also a Collection and Sequence
- String is also a Collection and Sequence
- ... is also a Collection and Sequence

- Can write code that works on all of them!

Protocol Extensions

```
protocol Sequence {
  associatedtype Element
  func makeIterator() -> Iterator
  func contains(Element) -> Bool
  func contains(where: (Element) -> Bool) -> Bool
  func first(where: (Element) -> Bool) -> Element?
  func min() -> Element?
  func max() -> Element?
  func sorted() -> [Element]
  func reversed() -> [Element]
  func map<T>((Element) -> T) -> [T]
  func filter((Element) -> Bool) -> [Element]
  func prefix(Int) -> SubSequence
}
```

```
class Queue: Sequence {
 typealias Element = Int
 private var elems: [Int]

 func makeIterator() -> Iterator {..}
 func add(_ elem : Int) { ... }
 func remove() : Int { ... }
 var count : Int
}
```

```
// Client
let q = Queue()
...
let max = q.max()
let pos = q.filter { $0 > 0 }

if q.contains { abs($0) > 10 }
for x in q {
  ...
}
```

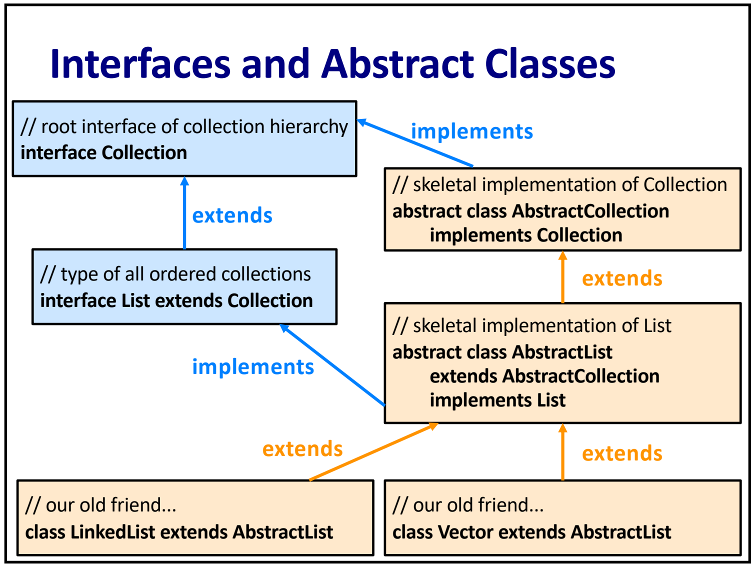
Protocol


```
protocol Sequence {
  associatedtype Element
  func makeIterator() -> Iter
  func contains(Element) -> Bool
  func contains(where: (Element)
  func first(where: (Element) ->
  func min() -> Element?
  func max() -> Element?
  func sorted() -> [Element]
  func reversed() -> [Element]
  func map<T>((Element) -> T) ->
  func filter((Element) -> Bool)
  func prefix(Int) -> SubSequence
}
```


```
// only uses Seq. protocol methods
extension Sequence {
  func filter(is Included(Element) -> Bool)
           -> [Element] {
    var result = [Element]()
    var iterator = self.makeIterator()
    while let element = iterator.next() {
      if isIncluded(element) {
        result.append(element)
      }
    }
    return Array(result)
  }
  ...
}
```


```
class Queue: Sequence {
 typealias Element = Int
 private var elems: [Int]

 func makeIterator() -> Iterator {..}
 func add(_ elem : Int) { ... }
 func remove() : Int { ... }
 var count : Int
}
```

```
// Client
let q = Queue()
...
let max = q.max()
let pos = q.filter { $0 > 0 }

if q.contains { abs($0) > 10 }
for x in q {
  ...
}
```


Interfaces and Abstract Classes
// root interface of collection hierarchy
interface Collection
implements
// skeletal implementation of Collection
abstract class AbstractCollection
implements Collection
extends
// type of all ordered collections
interface List extends Collection
extends
// skeletal implementation of List
abstract class AbstractList
extends AbstractCollection
implements List
implements
extends
extends
// our old friend...
class LinkedList extends AbstractList
// our old friend...
class Vector extends AbstractList