Developer Tools #WWDC15

Protocol-Oriented Programming in Swift

Session 408

Dave Abrahams Professor of Blowing-Your-Mind

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Meet Crusty

Don’t call him “Jerome”

Classes Are Awesome

Classes Are Awesome

- Encapsulation

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- Encapsulation
- Access Control

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- Abstraction

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Types Are Awesome

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- Extensibility

I can do all that with structs

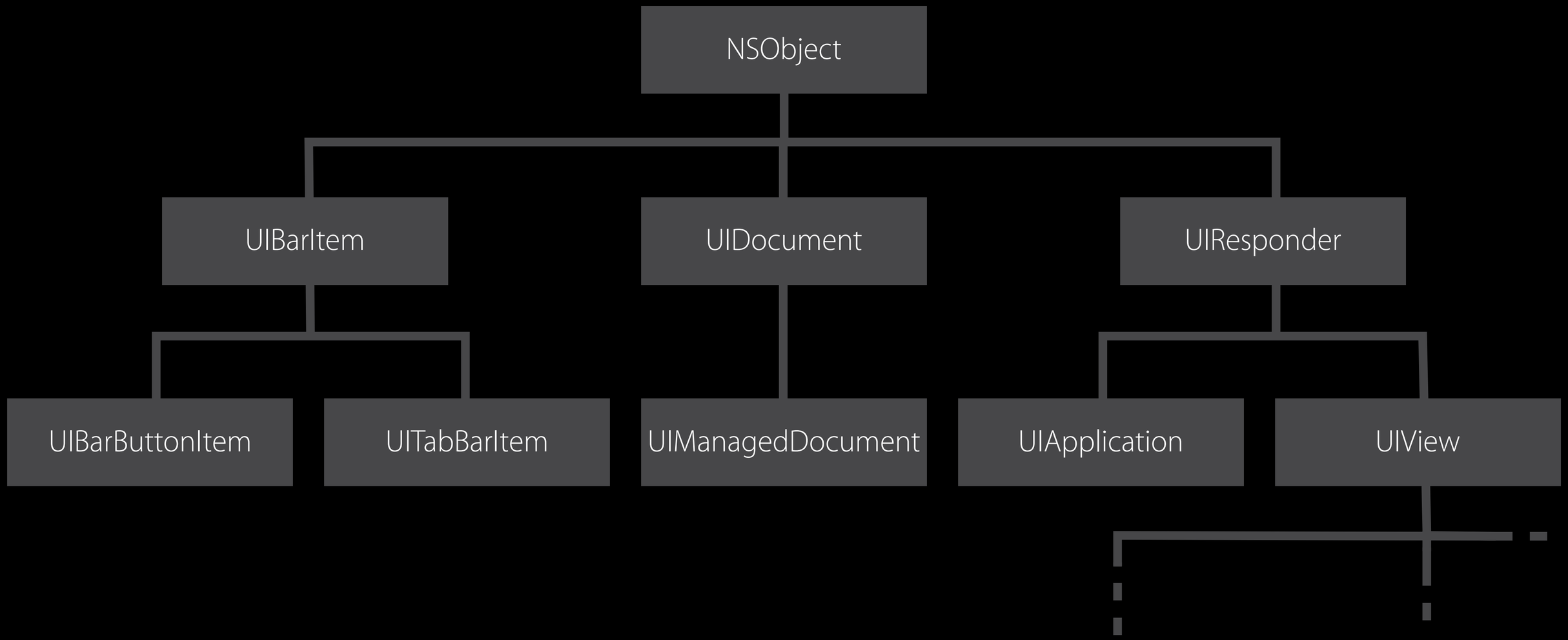
Classes Types Are Awesome

- Encapsulation
- Access Control
- Abstraction
- Namespace
- Expressive Syntax
- Extensibility

I can do all that with structs and enums.

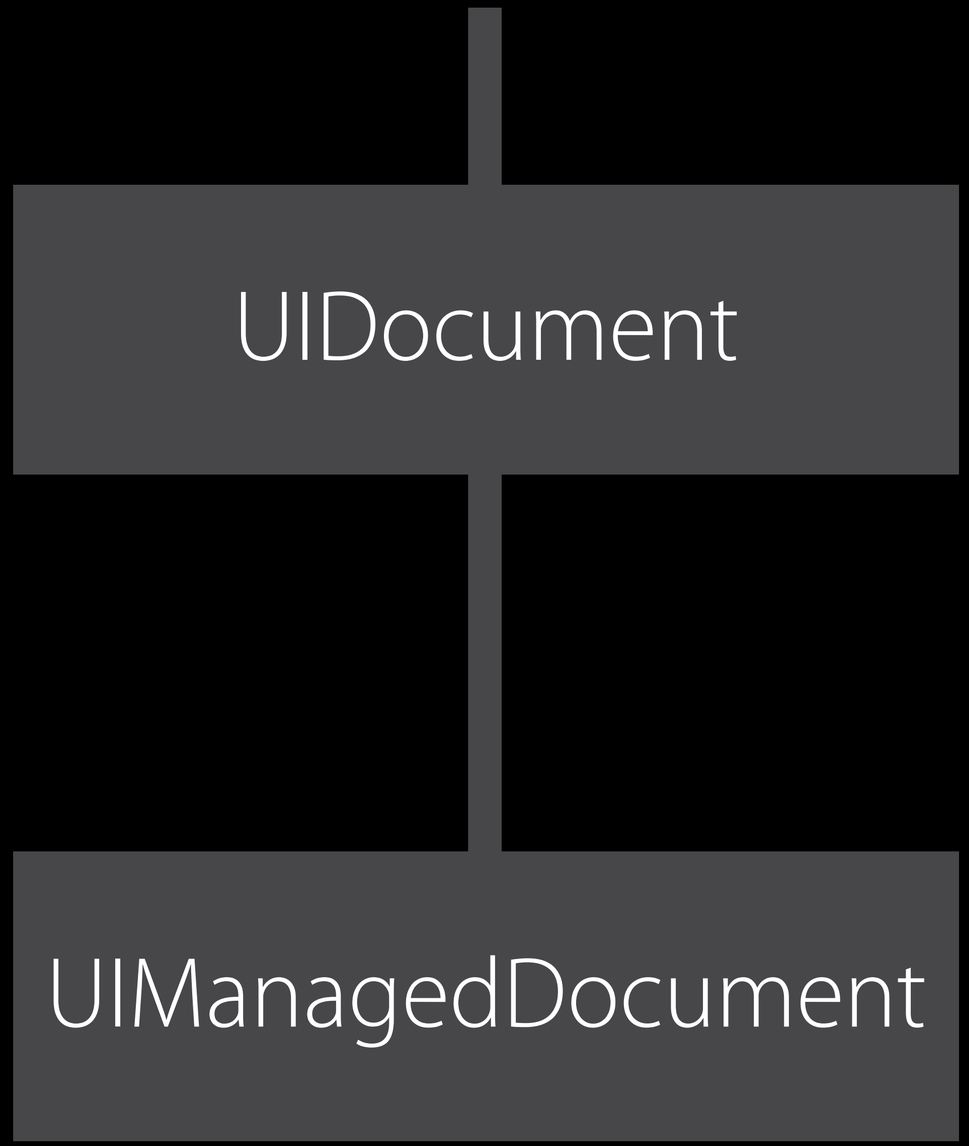
Classes Are Awesome

Inheritance Hierarchies



Classes Are Awesome

Customization points and reuse



Classes Are Awesome

Customization points and reuse

saveToURL(_:forSaveOperation:completionHandler:)

UIDocument

UIManagedDocument

Classes Are Awesome

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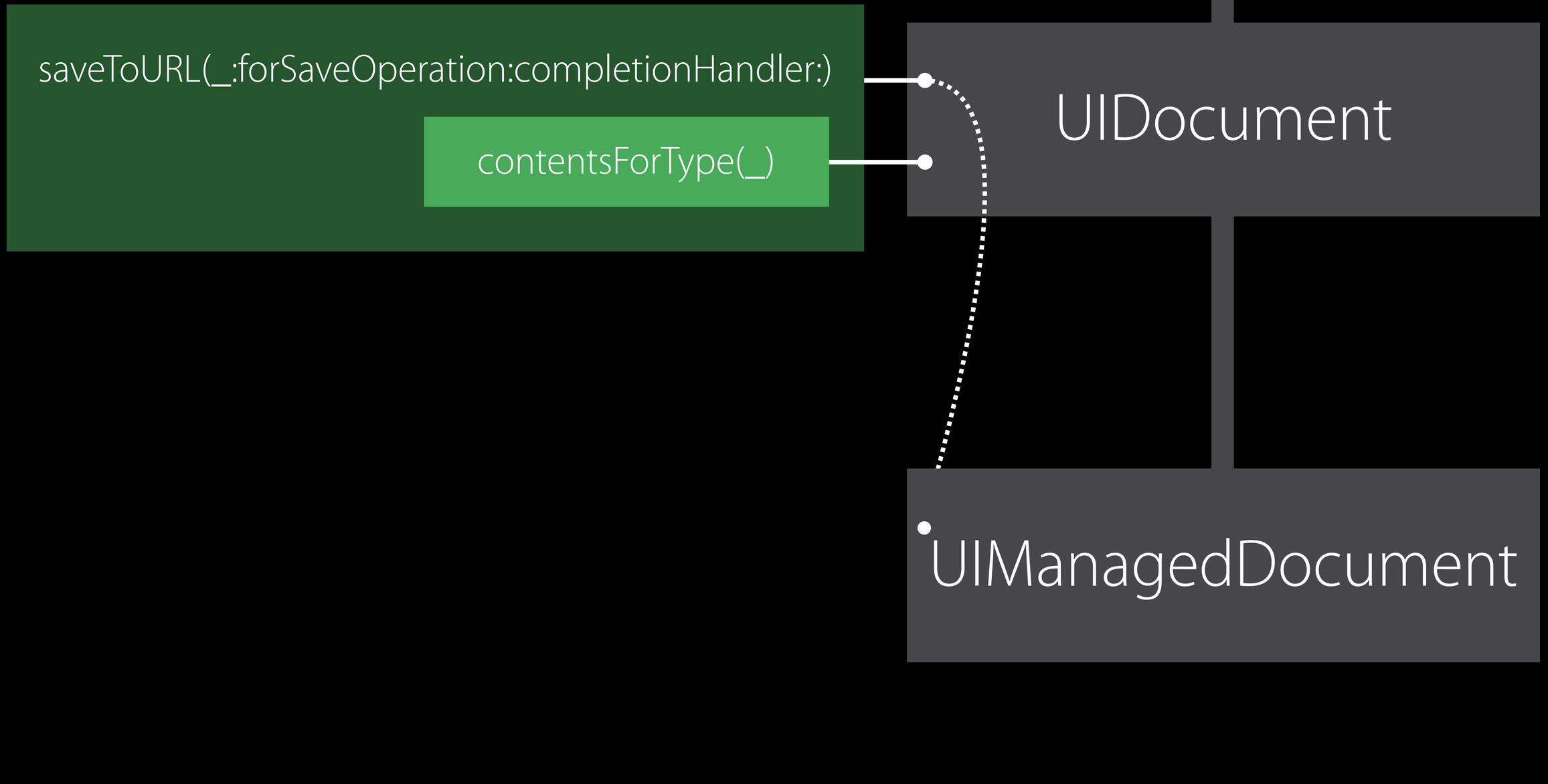
Customization points and reuse



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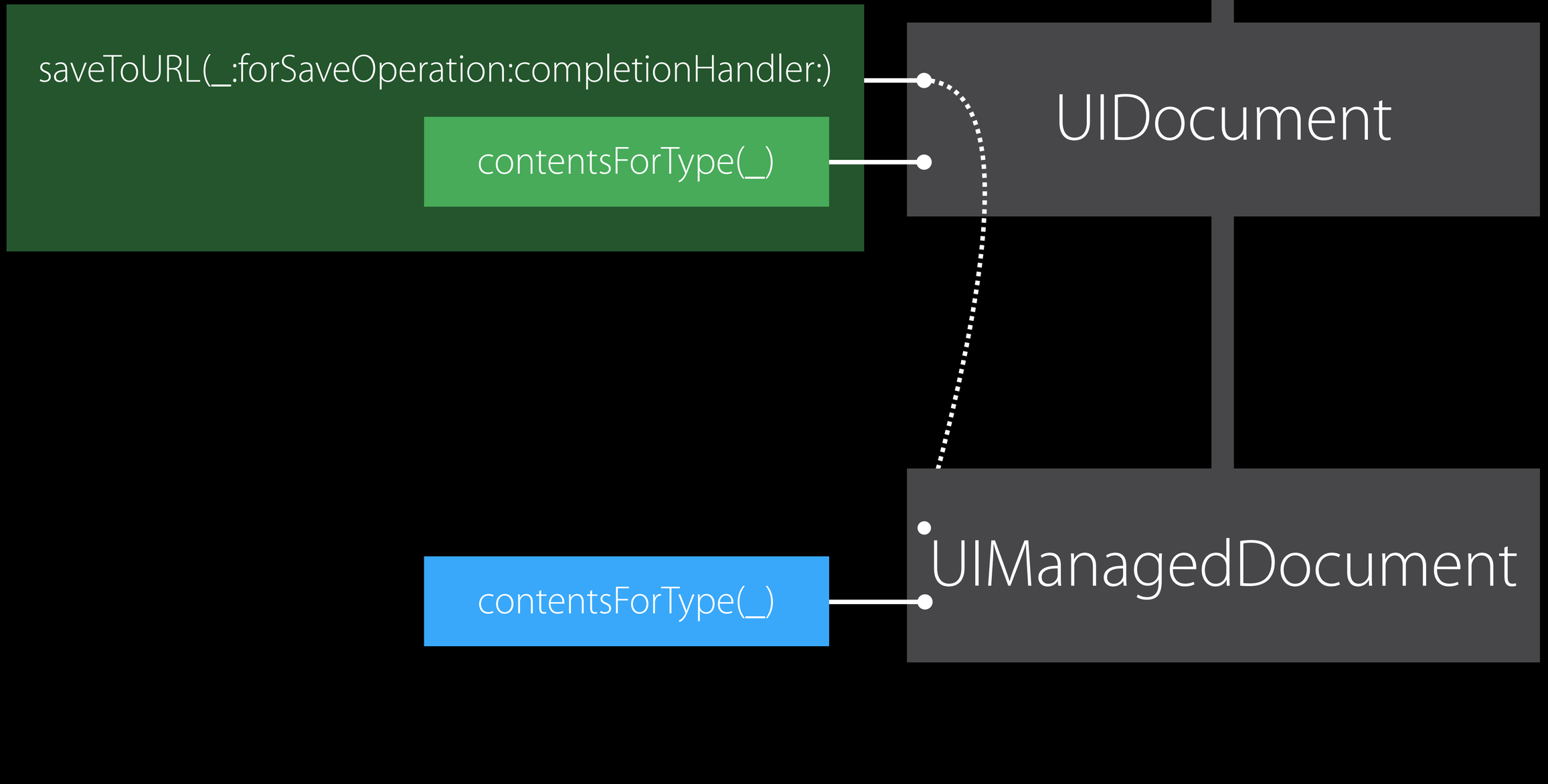

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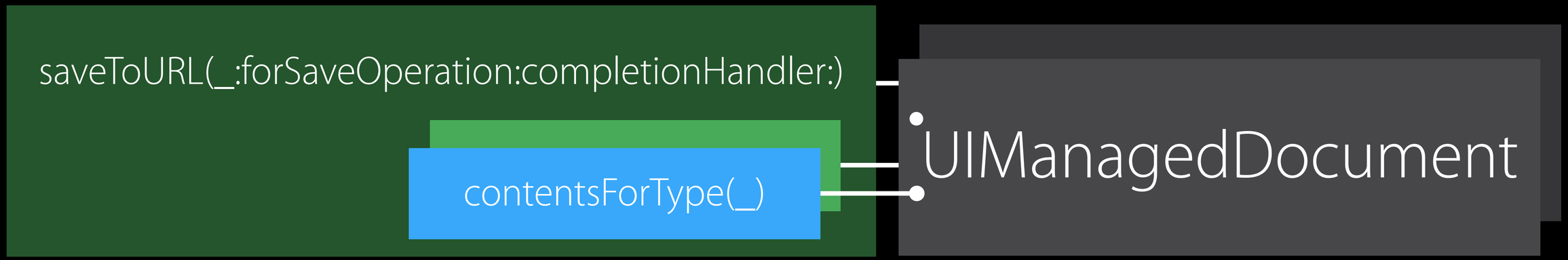

The Three Beefs

Crusty's litany of complaints

1. Implicit Sharing

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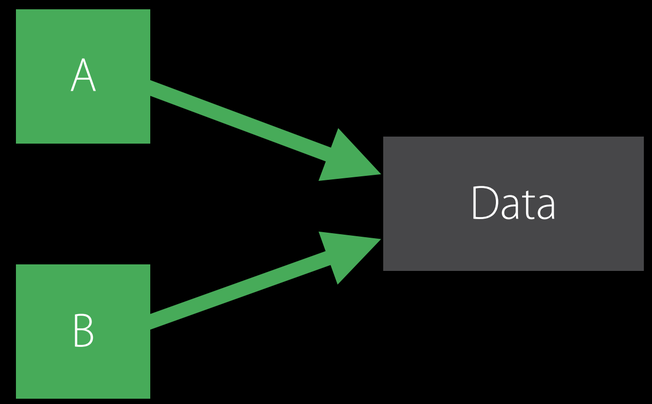

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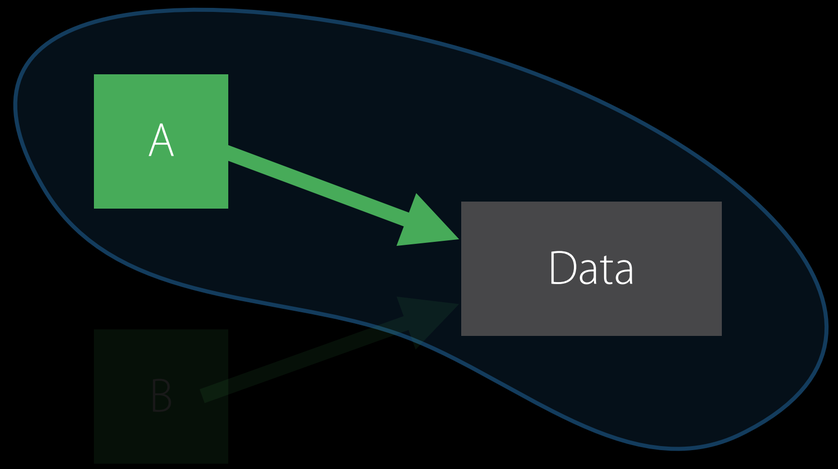

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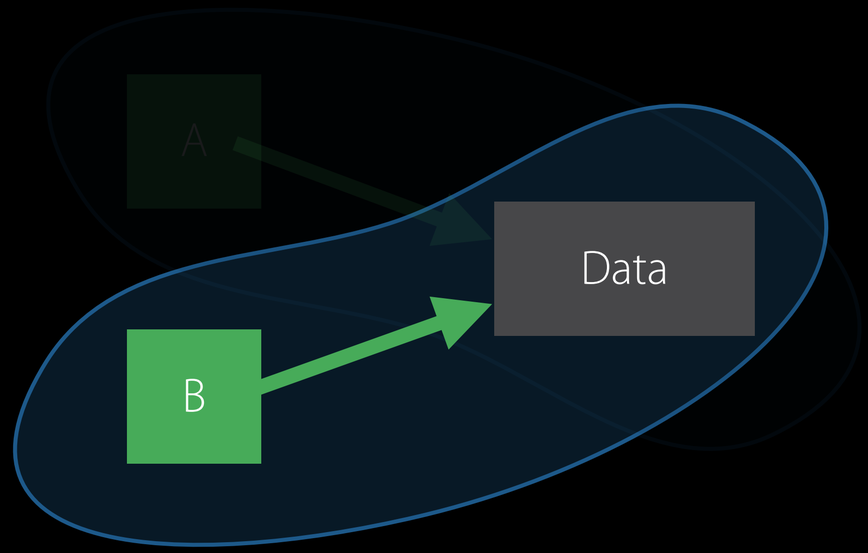

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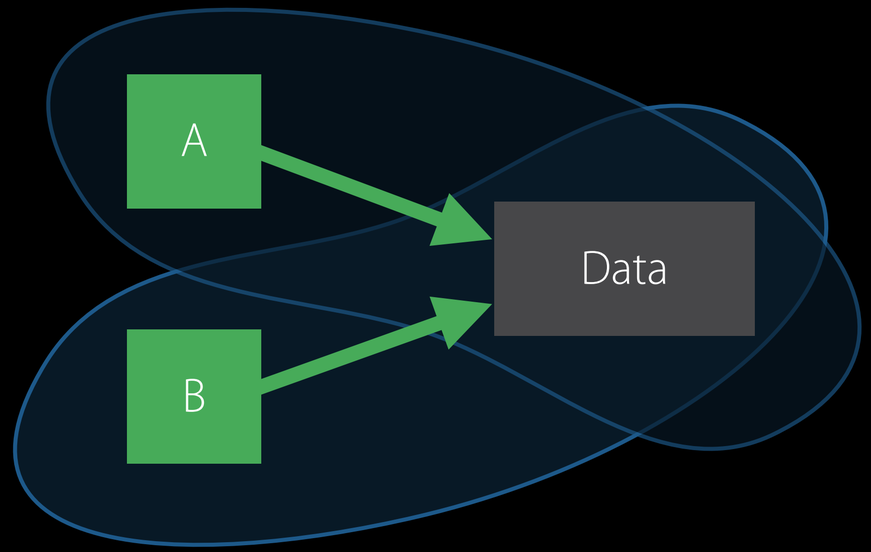

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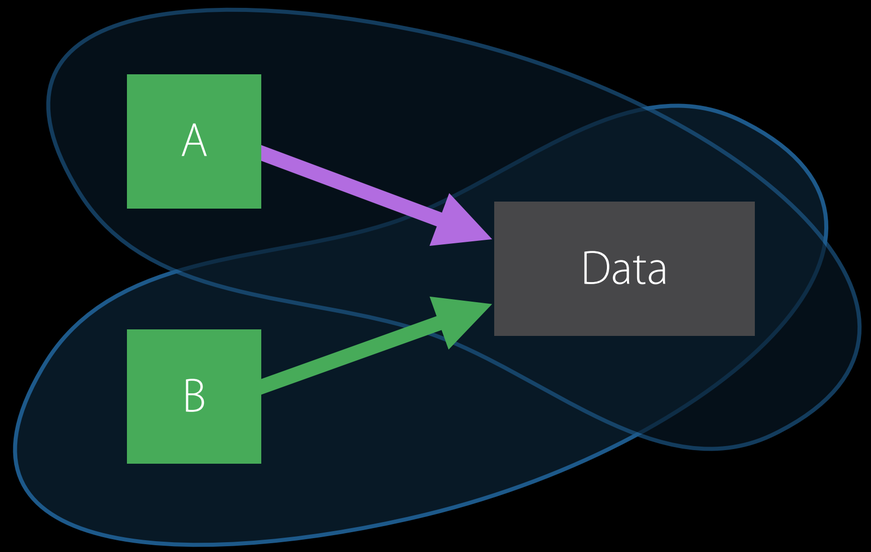

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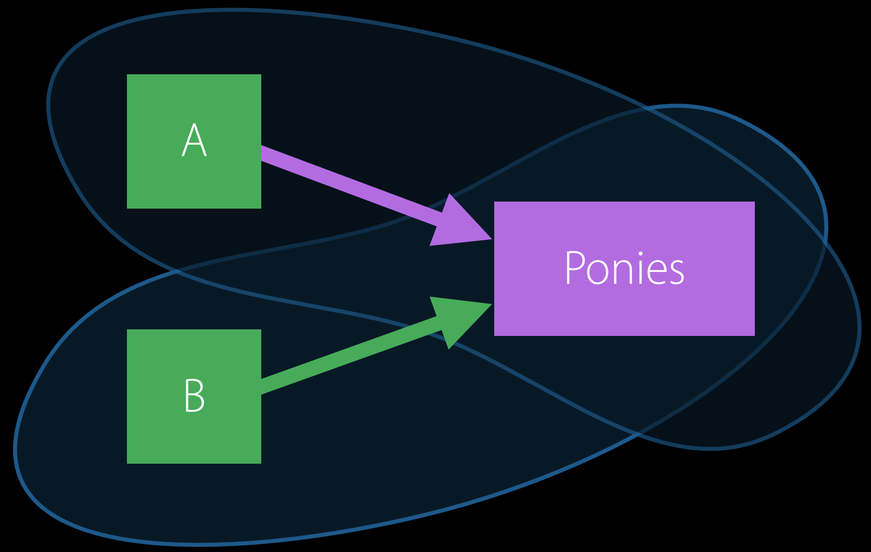

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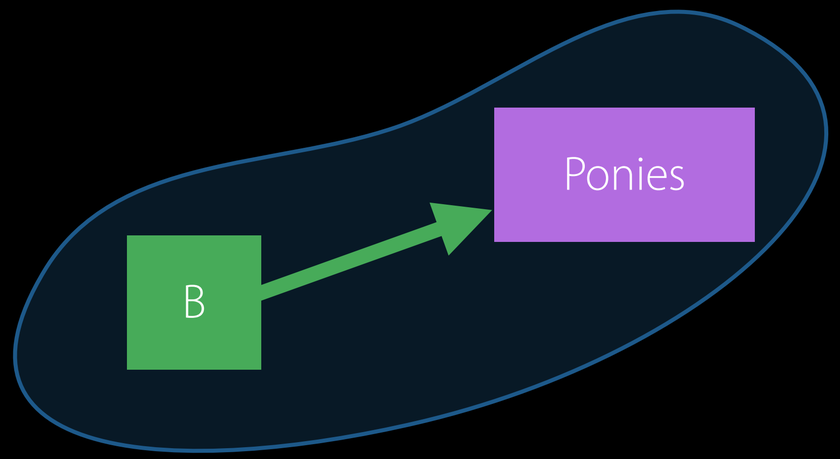

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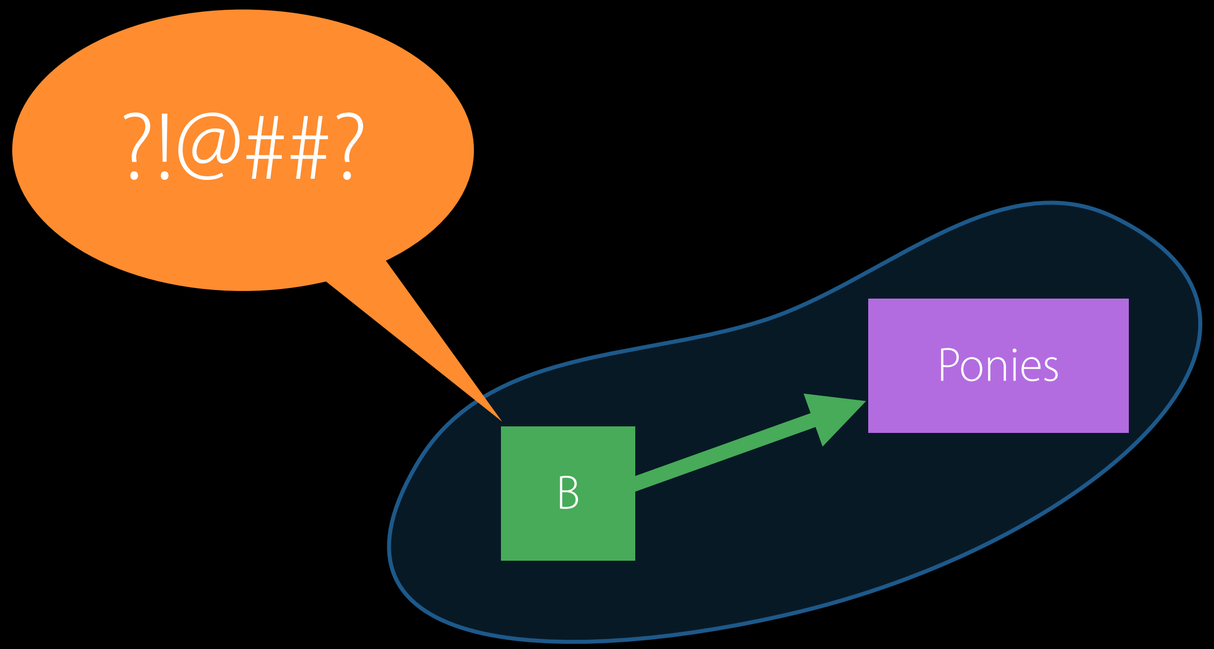

1. Implicit Sharing

The sad story

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Defensive Copying

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Inefficiency

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Race Conditions

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Complexity

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The sad story

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Complexity

Bugs!

This is not news.

@property(copy), coding conventions…

1. Implicit Sharing

> NOTE
>
> It is not safe to modify a mutable collection while enumerating through it. Some enumerators may currently allow enumeration of a collection that is modified, but this behavior is not guaranteed to be supported in the future.

One effect of implicit sharing on Cocoa

1. Implicit Sharing

NOTE

It is not safe to modify a mutable collection while enumerating through it. Some enumerators may currently allow enumeration of a collection that is modified, but this behavior is not guaranteed to be supported in the future.

Cocoa Collections Only

One effect of implicit sharing on Cocoa

Values Don't Share.

(That's a good thing).

Classes? They overshare.

Building Better Apps with Value Types in Swift	Mission	Friday 2:30PM

2. Inheritance All Up In Your Business

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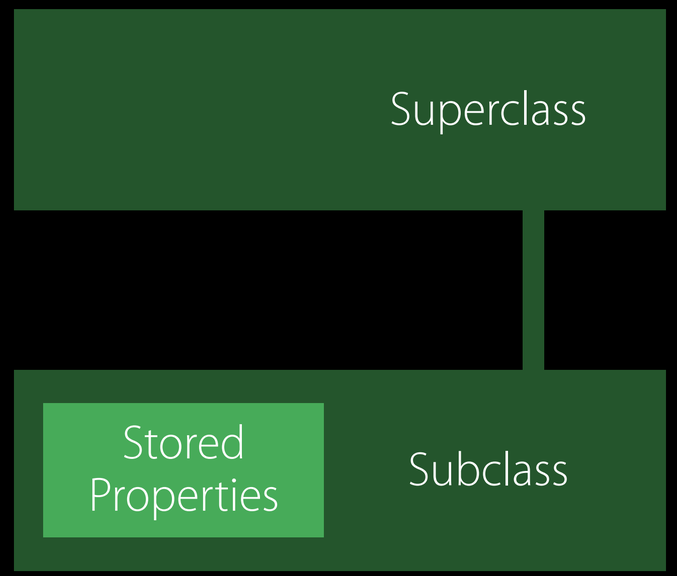
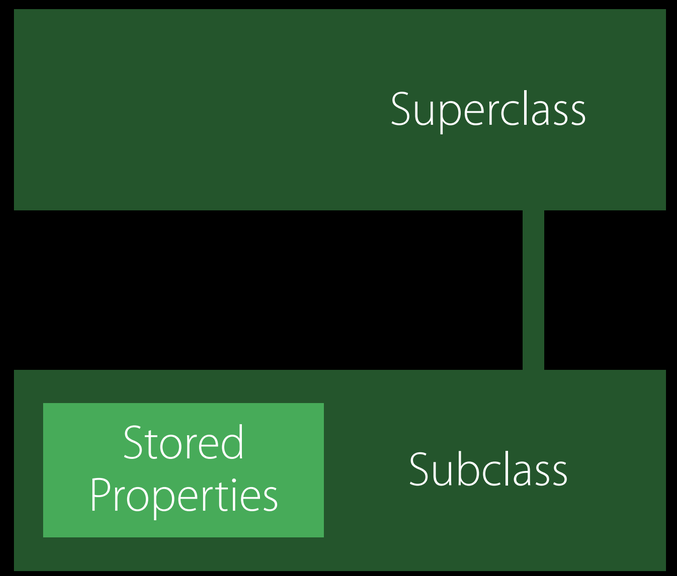
One superclass — choose well!



2. Inheritance All Up In Your Business

One superclass — choose well!

Single Inheritance weight gain



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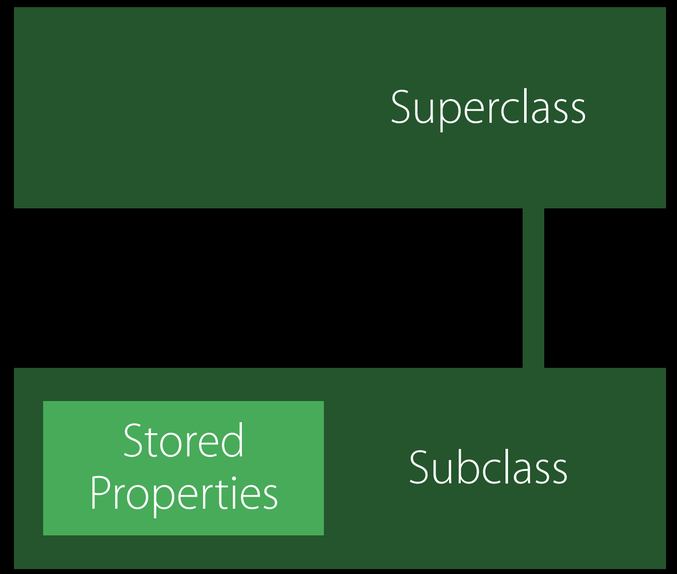

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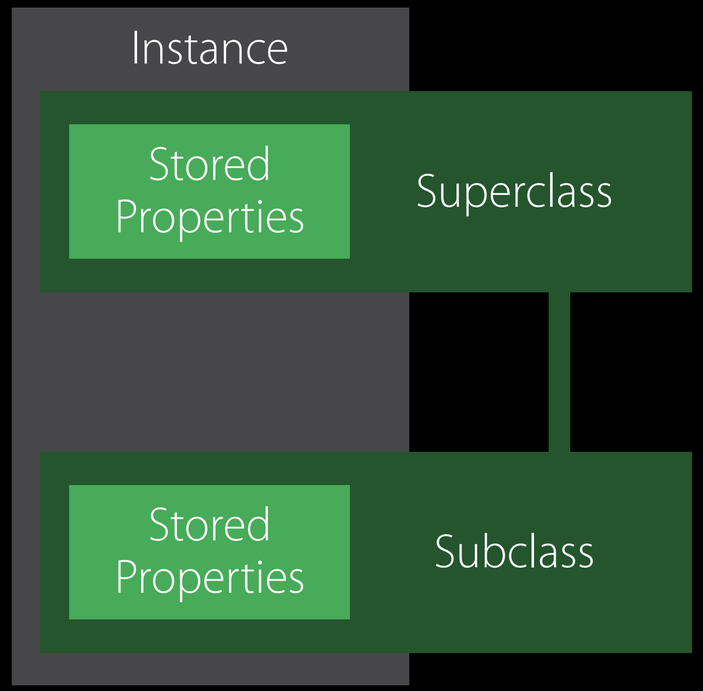
Superclass may have stored properties



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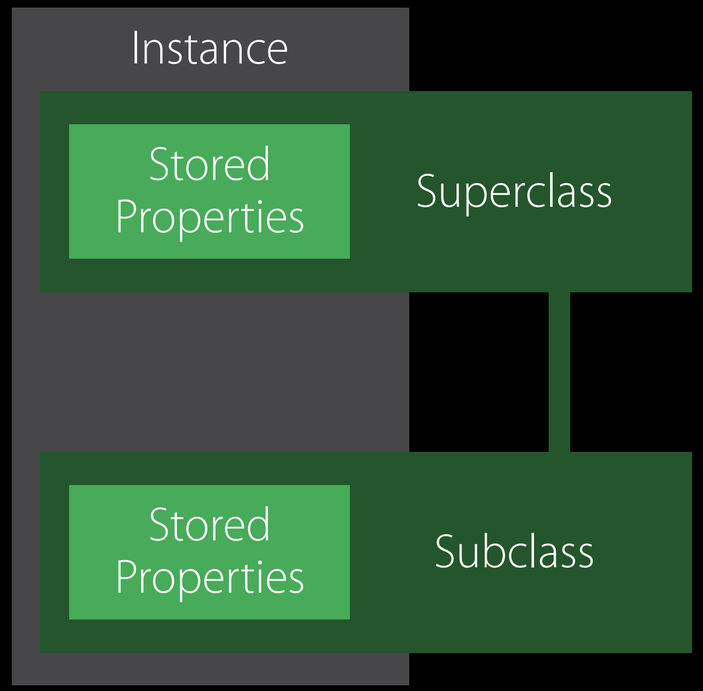
Superclass may have stored properties

- You must accept them



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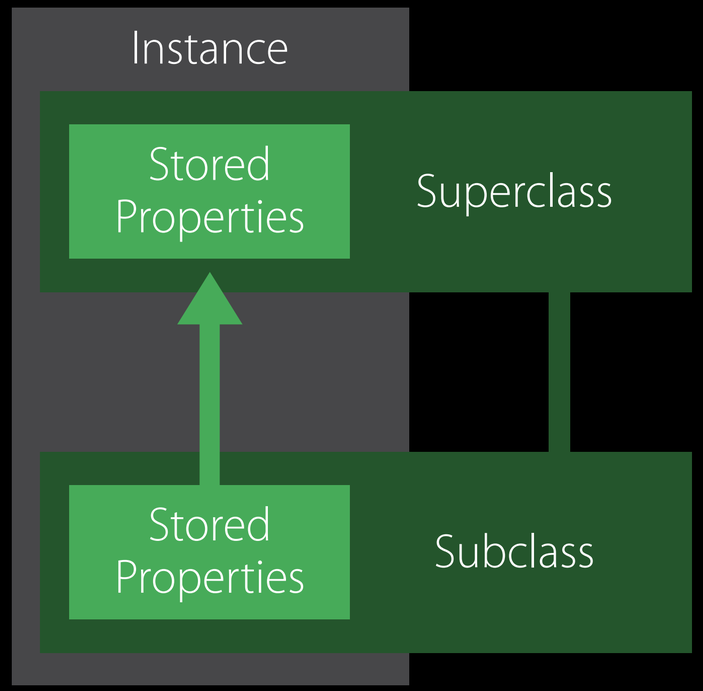

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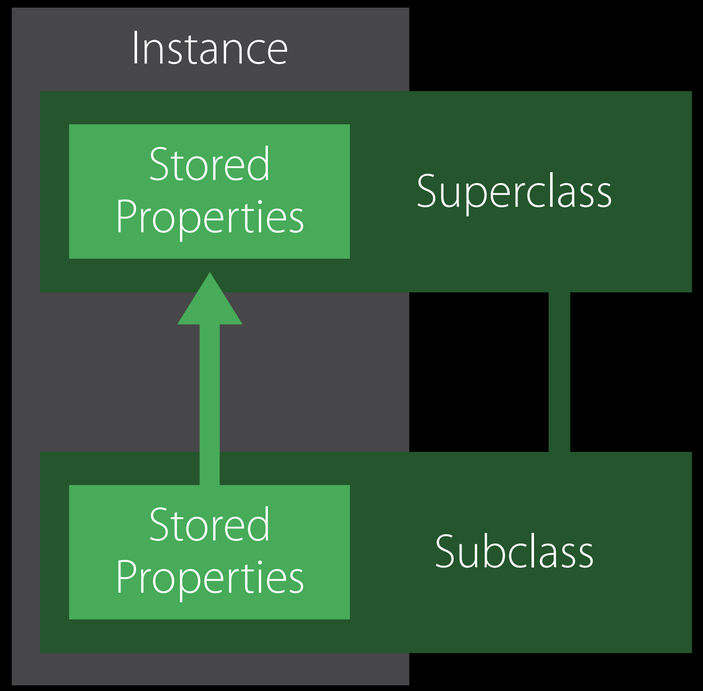

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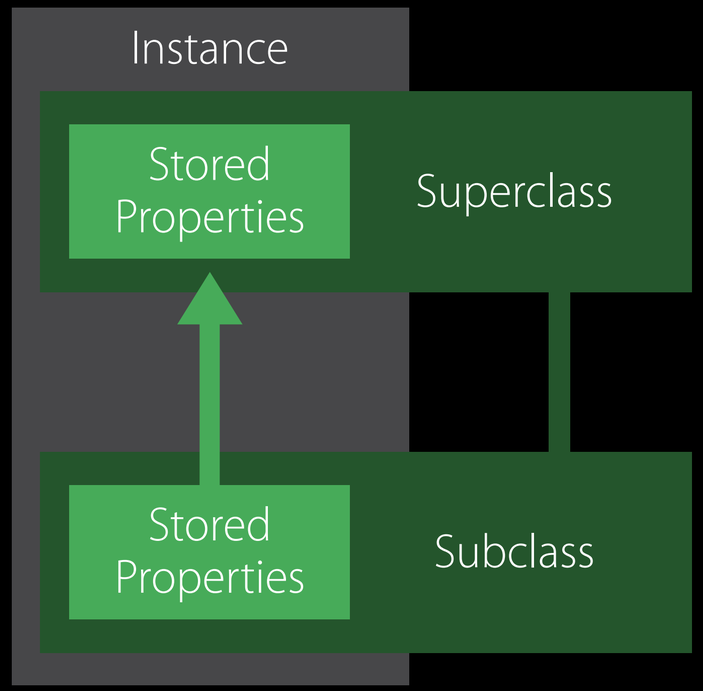
Know what/how to override (and when not to)



This is not news.

More and more, we promote delegation.

3. Lost Type Relationships

```
class Ordered {
  func precedes(other: Ordered) -> Bool
}

func binarySearch(sortedKeys: [Ordered], forKey k: Ordered) -> Int {
  var lo = 0, hi = sortedKeys.count
  while hi > lo {
    let mid = lo + (hi - lo) / 2
    if sortedKeys[mid].precedes(k) { lo = mid + 1 }
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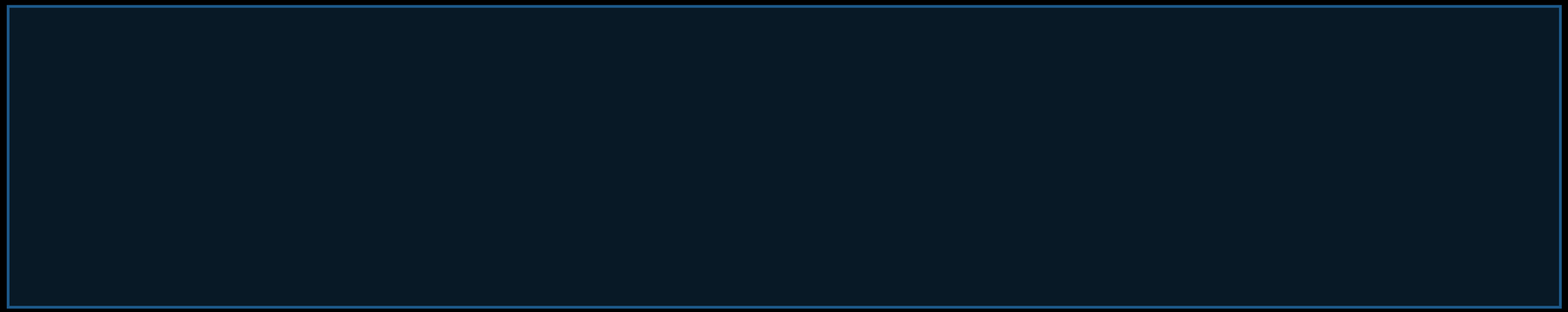

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```

as! ASubclass

A sign that a type relationship was lost
Usually due to using classes for abstraction

A Better Abstraction Mechanism

Supports value types (and classes)

Supports static type relationships (and dynamic dispatch)

Non-monolithic

Supports retroactive modeling

Doesn’t impose instance data on models

Doesn’t impose initialization burdens on models

Makes clear what to implement

Swift Is a Protocol-Oriented Programming Language

Start with a Protocol

Your first stop for new abstractions

Starting Over with Protocols

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error: protocol methods may not have bodies

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  }
}
```

error: method does not override any method from its superclass

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protocol requires function 'precedes' with type '(Ordered) -> Bool'
candidate has non-matching type '(Number) -> Bool'

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Starting Over with Protocols

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}

struct Number : Ordered {
  var value: Double = 0
  func precedes(other: Number) -> Bool {
    return self.value < other.value
  }
}
```

Starting Over with Protocols

"Self" requirement

```
protocol Ordered {
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Using Our Protocol

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func binarySearch(sortedKeys: [Ordered], forKey k: Ordered) -> Int {
  var lo = 0
  var hi = sortedKeys.count
  while hi > lo {
    let mid = lo + (hi - lo) / 2
    if sortedKeys[mid].precedes(k) { lo = mid + 1 }
    else { hi = mid }
  }
  return lo
}
```

protocol 'Ordered' can only be used as a generic constraint because it has Self or associated type requirements

Using Our Protocol

```
func binarySearch(sortedKeys: [Ordered], forKey k: Ordered) -> Int {
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Using Our Protocol

```
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int {
  var lo = 0
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  return lo
}
```

Two Worlds of Protocols

Without Self Requirement	With Self Requirement
`func precedes(other: Ordered) -> Bool`	`func precedes(other: Self) -> Bool`

Two Worlds of Protocols

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Every model must deal with all others	Models are free from interaction

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Think "heterogeneous"	Think "homogeneous"
Every model must deal with all others	Models are free from interaction
Dynamic dispatch	Static dispatch
Less optimizable	More optimizable

A Challenge for Crusty

Prove it!

A Primitive “Renderer”

```
struct Renderer {
  func moveTo(p: CGPoint) { print("moveTo(\(p.x), \(p.y))") }

  func lineTo(p: CGPoint) { print("lineTo(\(p.x), \(p.y))") }

  func arcAt(center: CGPoint, radius: CGFloat,
             startAngle: CGFloat, endAngle: CGFloat) {
      print("arcAt(\(center), radius: \(radius),"
        + " startAngle: \(startAngle), endAngle: \(endAngle))")
  }
}
```

Drawable

```
protocol Drawable {
  func draw(renderer: Renderer)
}
```

Polygon

```
protocol Drawable {
  func draw(renderer: Renderer)
}

struct Polygon : Drawable {
  func draw(renderer: Renderer) {
    renderer.moveTo(corners.last!)
    for p in corners {
      renderer.lineTo(p)
    }
  }
  var corners: [CGPoint] = []
}
```

Polygon

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protocol Drawable {
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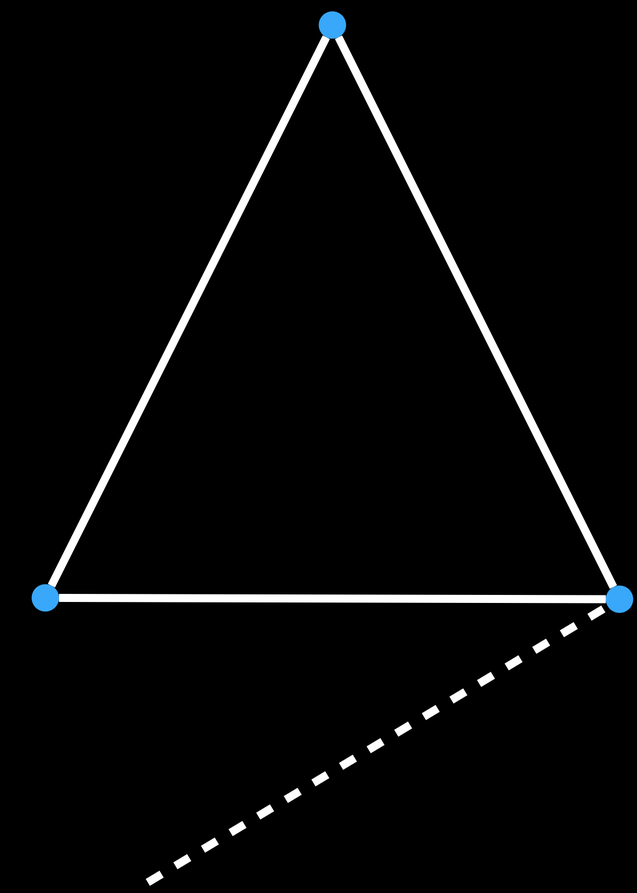
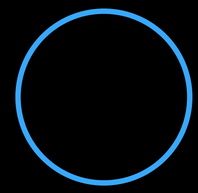


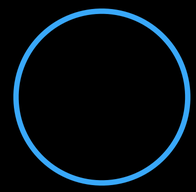
Circle



```
protocol Drawable {
  func draw(renderer: Renderer)
}

struct Circle : Drawable {
  func draw(renderer: Renderer) {
    renderer.arcAt(center, radius: radius,
      startAngle: 0.0, endAngle: twoPi)
  }
  var center: CGPoint
  var radius: CGFloat
}
```

Circle



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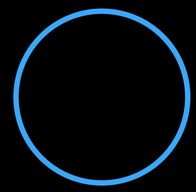

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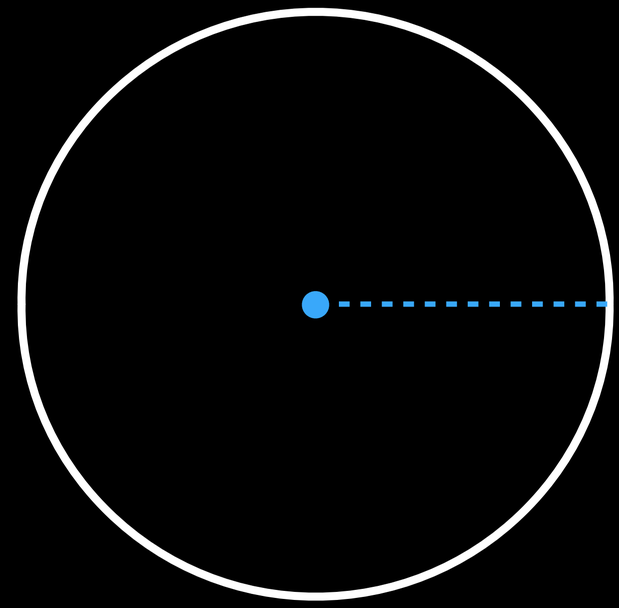

Diagram

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) {
    for f in elements {
      f.draw(renderer)
    }
  }
  var elements: [Drawable] = []
}
```

Diagram

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) {
    for f in elements {
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    }
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  var elements: [Drawable] = []
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    }
  }
  var elements: [Drawable] = []
}
```

Test It!

```
var circle = Circle(center:
  CGPoint(x: 187.5, y: 333.5),
  radius: 93.75)
```

Test It!

```
var circle = Circle(center:
  CGPoint(x: 187.5, y: 333.5),
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var triangle = Polygon(corners: [
  CGPoint(x: 187.5, y: 427.25),
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])
```

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var diagram = Diagram(elements: [circle, triangle])

diagram.draw(Renderer())
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```
var circle = Circle(center:
  CGPoint(x: 187.5
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  CGPoint(x: 187.5
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```
$ ./test
```

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  CGPoint(x: 187.5
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var triangle = Pol
  CGPoint(x: 187.5
  CGPoint(x: 268.6
  CGPoint(x: 106.3

var diagram = Diag

diagram.draw(Renderer())
```

```
$ ./test
arcAt((187.5, 333.5),
  radius: 93.75, startAngle: 0.0,
  endAngle: 6.28318530717959)
moveTo(106.310118395209, 286.625)
lineTo(187.5, 427.25)
lineTo(268.689881604791, 286.625)
lineTo(106.310118395209, 286.625)
$
```

Renderer as a Protocol

```
struct Renderer {
  func moveTo(p: CGPoint) { print("moveTo(\(p.x), \(p.y))") }
  func lineTo(p: CGPoint) { print("lineTo(\(p.x), \(p.y))") }
  func arcAt(center: CGPoint, radius: CGFloat,
             startAngle: CGFloat, endAngle: CGFloat) {
    print("arcAt(\(center), radius: \(radius),"
      + " startAngle: \(startAngle), endAngle: \(endAngle))")
  }
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}


struct TestRenderer : Renderer {
  func moveTo(p: CGPoint) { print("moveTo(\(p.x), \(p.y))") }
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Rendering with CoreGraphics

Retroactive modeling

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}

extension CGContext : Renderer {
  func moveTo(p: CGPoint) {  }
  func lineTo(p: CGPoint) {  }
  func arcAt(center: CGPoint, radius: CGFloat,
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             startAngle: CGFloat, endAngle: CGFloat) {



  }
}
```

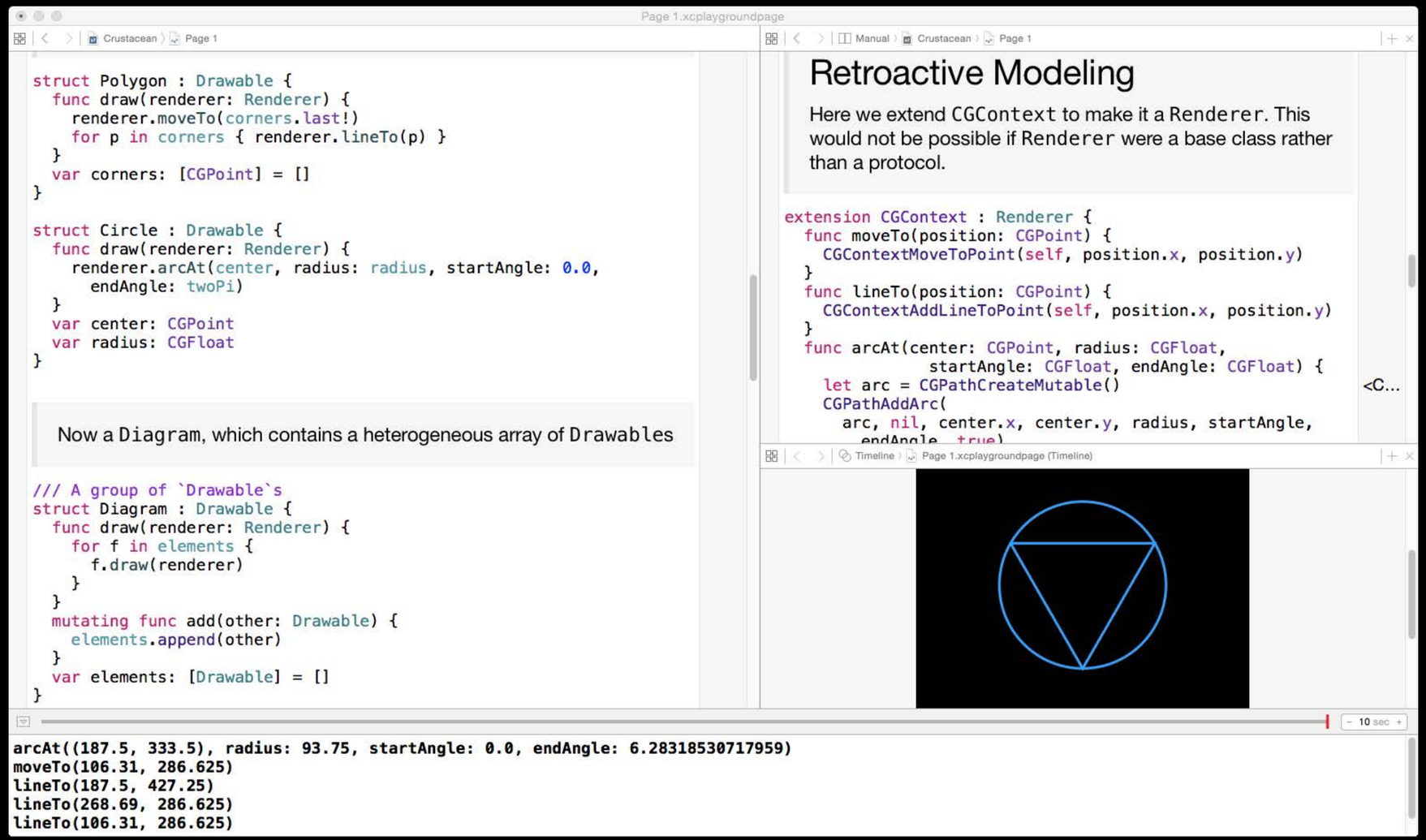
Rendering with CoreGraphics

Retroactive modeling

```
extension CGContext : Renderer {
  func moveTo(p: CGPoint) {
    CGContextMoveToPoint(self, position.x, position.y)
  }
  func lineTo(p: CGPoint) {
    CGContextAddLineToPoint(self, position.x, position.y)
  }
  func arcAt(center: CGPoint, radius: CGFloat,
             startAngle: CGFloat, endAngle: CGFloat) {
    let arc = CGPathCreateMutable()
    CGPathAddArc(arc, nil, c.x, c.y, radius, startAngle, endAngle, true)
    CGContextAddPath(self, arc)
  }
}
```

Crustacean: The Playground

https://developer.apple.com/sample-code/wwdc/2015/

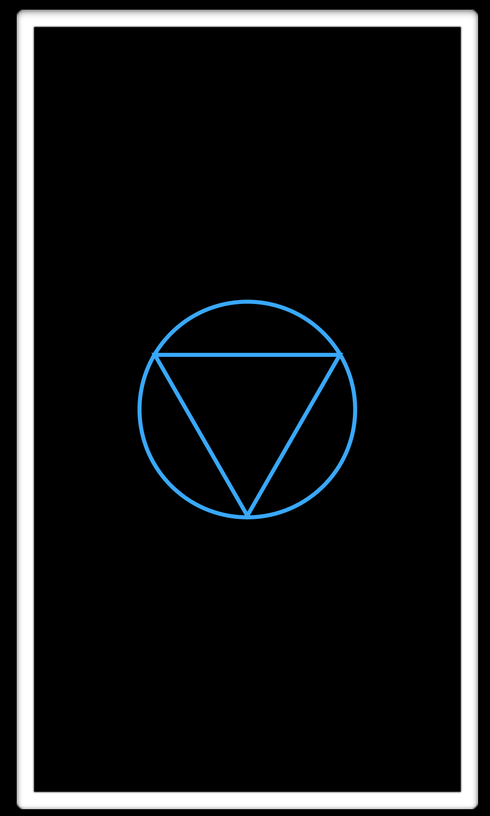


Nested Diagram

```
var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

var triangle = Polygon(corners: [
  CGPoint(x: 187.5, y: 427.25),
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])

var diagram = Diagram(elements: [circle, triangle])
```



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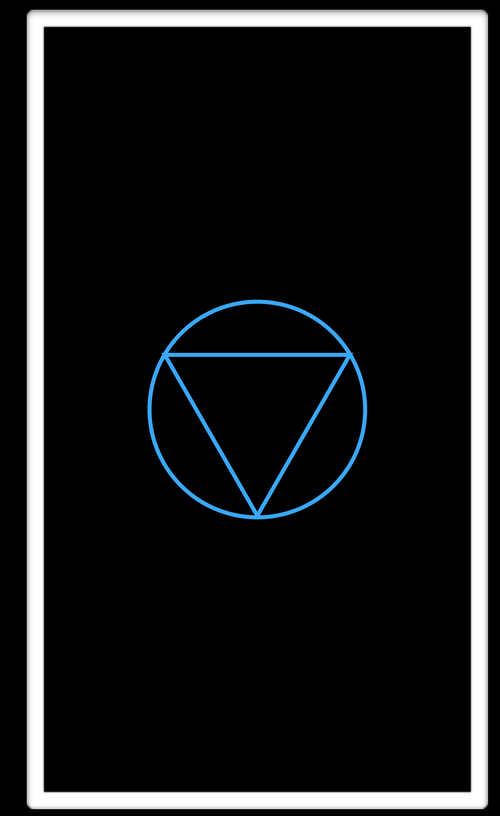
  CGPoint(x: 106.31, y: 286.625)])

var diagram = Diagram(elements: [circle, triangle])

diagram.elements.append(diagram)
```



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var triangle = Polygon(corners: [
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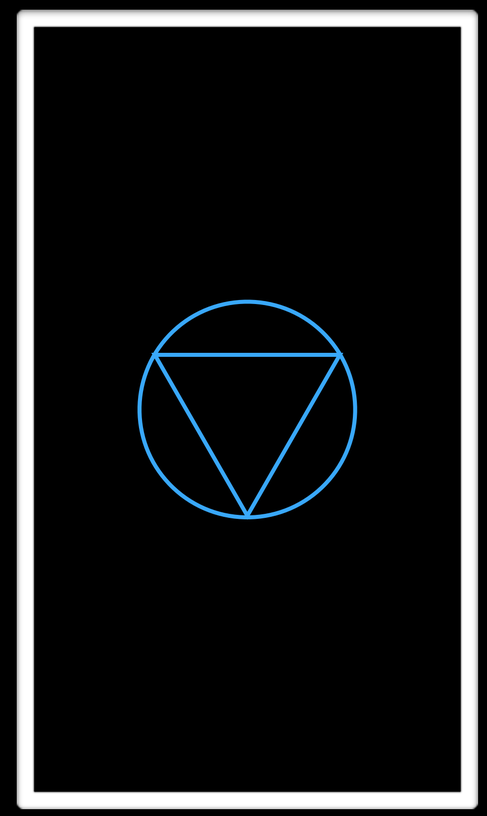
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])

var diagram = Diagram(elements: [circle, triangle])

diagram.elements.append(diagram)
```



Nested Diagram

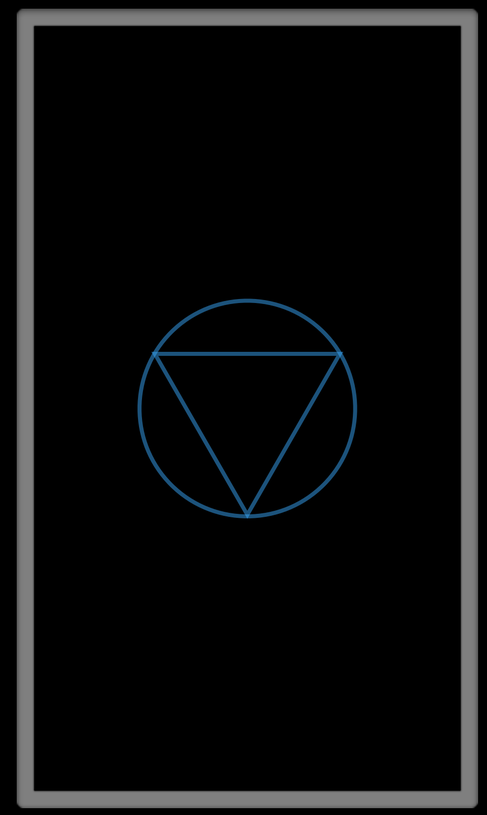
```
var circle = Circl

var triangle = Pol
  CGPoint(x: 187.5
  CGPoint(x: 268.6
  CGPoint(x: 106.3

var diagram = Diag

diagram.elements.a
```

```
$ ./test
arcAt((187.5, 333.5), radius: 93.75,
startAngle: 0.0, endAngle: 6.28318530717959)
moveTo(106.310118395209, 286.625)
lineTo(187.5, 427.25)
lineTo(268.689881604791, 286.625)
lineTo(106.310118395209, 286.625)
arcAt((187.5, 333.5), radius: 93.75,
startAngle: 0.0, endAngle: 6.28318530717959)
moveTo(106.310118395209, 286.625)
lineTo(187.5, 427.25)
lineTo(268.689881604791, 286.625)
lineTo(106.310118395209, 286.625)
$
```



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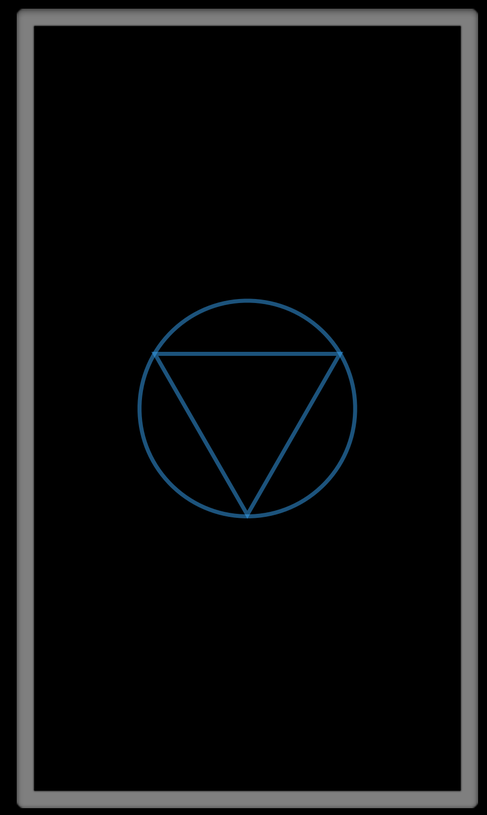

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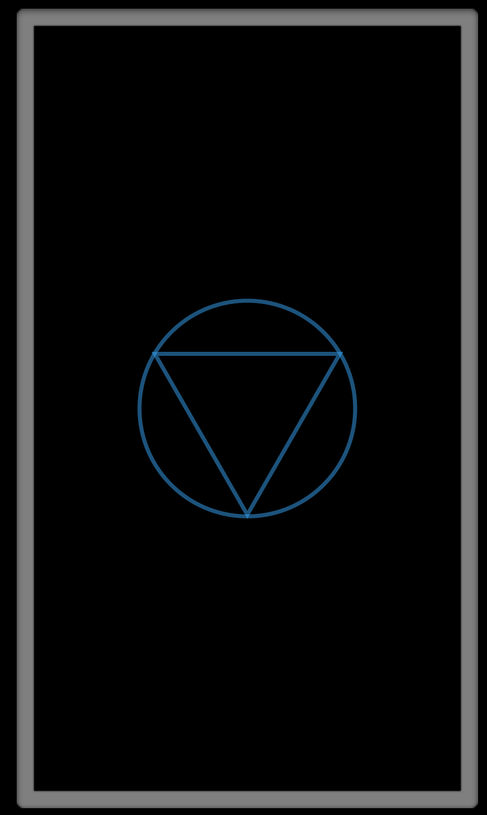

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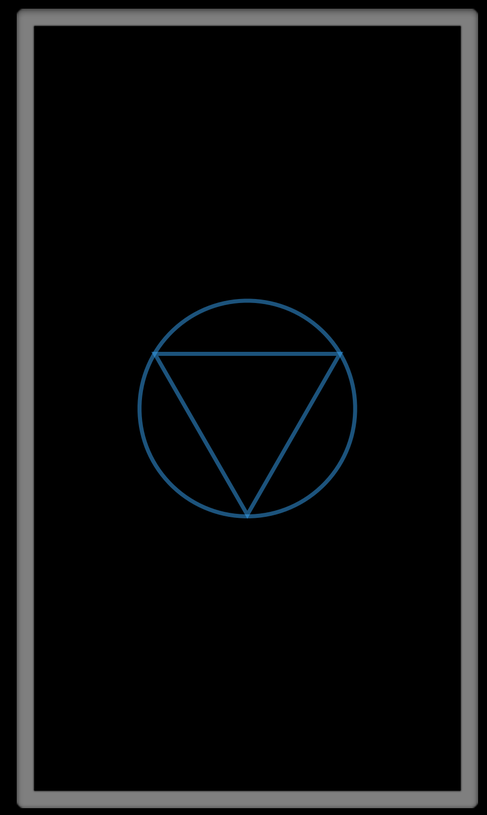


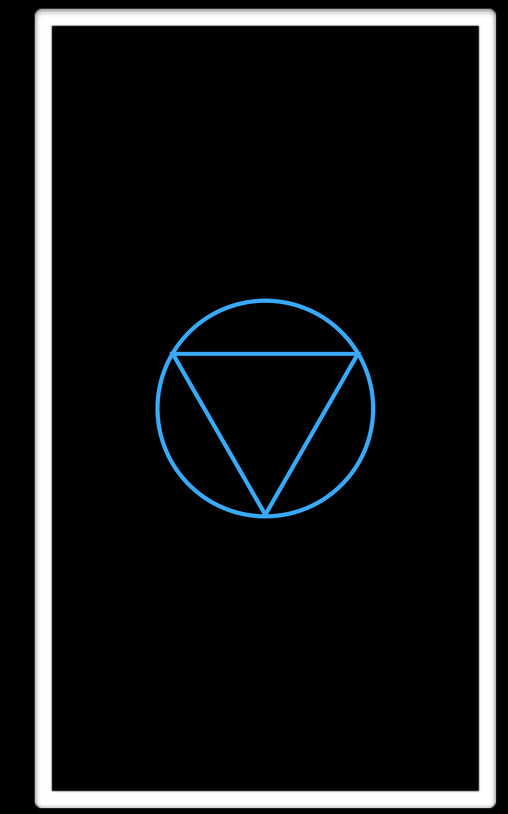
Nested Diagram

```
var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

var triangle = Polygon(corners: [
  CGPoint(x: 187.5, y: 427.25),
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])

var diagram = Diagram(elements: [circle, triangle])

diagram.elements.append(diagram)
```



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var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

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  CGPoint(x: 187.5, y: 427.25),
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diagram.elements.append(diagram)
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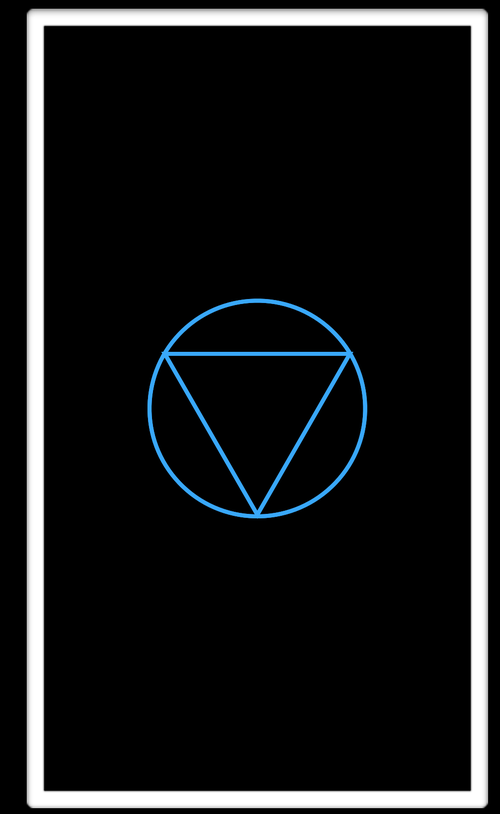

Nested Diagram

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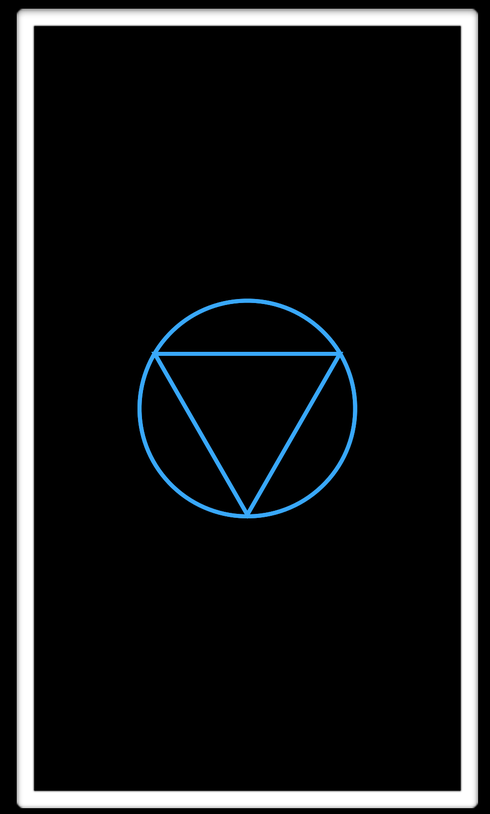
var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

var triangle = Polygon(corners: [
  CGPoint(x: 187.5, y: 427.25),
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])

var diagram = Diagram(elements: [circle, triangle])

diagram.elements.append(
  Scaled(scale: 0.3, subject: diagram))
```



Nested Diagram

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var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

var triangle = Polygon(corners: [
  CGPoint(x: 187.5, y: 427.25),
  CGPoint(x: 268.69, y: 286.625),
  CGPoint(x: 106.31, y: 286.625)])

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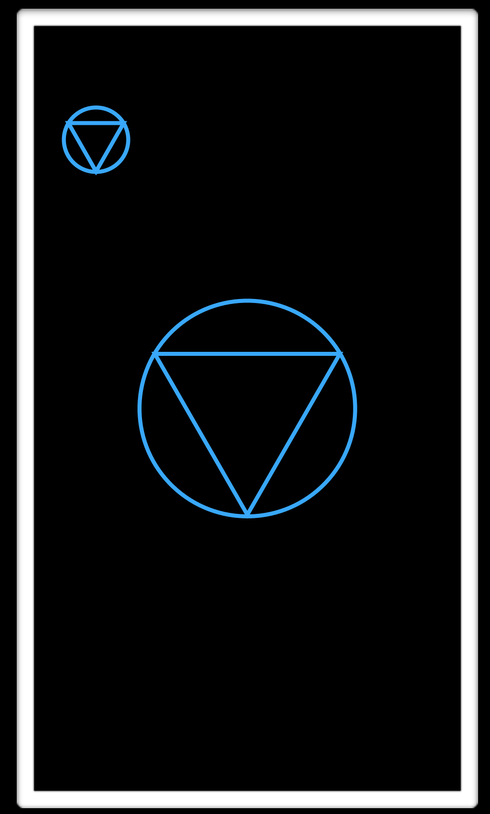

Nested Diagram

```
var circle = Circle(center: CGPoint(x: 187.5, y: 333.5), radius: 93.75)

var triangle = Polygon(corners: [
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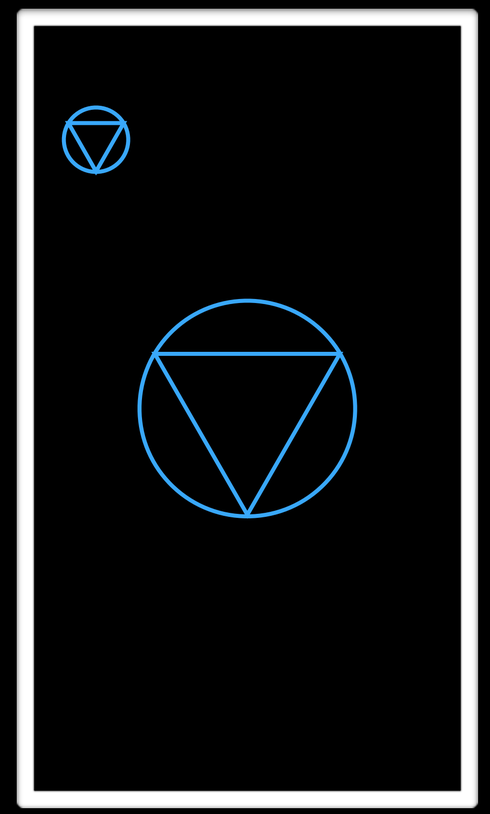


Protocols and Generics for Testability

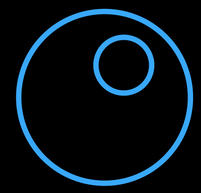
So much better than mocks

Disciplined decoupling is a beautiful thing.

Bubble

```
struct Bubble : Drawable {
  func draw(r: Renderer) {
    r.arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
    r.arcAt(highlightCenter, radius: highlightRadius,
        startAngle: 0, endAngle: twoPi)
  }
}
```

Bubble



```
struct Bubble : Drawable {
  func draw(r: Renderer) {
    r.arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
    r.arcAt(highlightCenter, radius: highlightRadius,
        startAngle: 0, endAngle: twoPi)
  }
}
struct Circle : Drawable {
  func draw(r: Renderer) {
    r.arcAt(center, radius: radius, startAngle: 0.0, endAngle: twoPi)
  }
}
```

Bubble

```
struct Bubble : Drawable {
  func draw(r: Renderer) {
    r.circleAt(center, radius: radius)
    r.circleAt(highlightCenter, radius: highlightRadius)
  }
}

struct Circle : Drawable {
  func draw(r: Renderer) {
    r.circleAt(center, radius: radius)
  }
}
```

Adding a Circle Primitive

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)

  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}
```

Adding a Circle Primitive

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)

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      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
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  func moveTo(p: CGPoint)
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  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}
```

Adding a Circle Primitive

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}
```

New requirement

Implementing the Requirement

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension TestRenderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

New requirement

Implementing the Requirement… Again!

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension CGContext {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Implementing the Requirement… Again!

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension CGContext {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Duplicate implementation

Implementing the Requirement… Again!

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension CGContext {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Protocol Extensions

NEW

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Protocol Extensions

NEW

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Protocol Extensions

NEW

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Shared implementation

Protocol Extensions

NEW

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
    arcAt(center, radius: radius, startAngle: 0, endAngle: twoPi)
  }
}
```

Protocol Extensions

Requirements create customization points

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
    center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
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extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) {
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  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }

}
```

Protocol Extensions

Requirements create customization points

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
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  func circleAt(center: CGPoint, radius: CGFloat) { ... }

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  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
  func arcAt(
      center: CGPoint, radius: CGFloat, startAngle: CGFloat, endAngle: CGFloat)
}

extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

Protocol Extensions

Requirements create customization points

```
protocol Renderer {
  func moveTo(p: CGPoint)
  func lineTo(p: CGPoint)
  func circleAt(center: CGPoint, radius: CGFloat)
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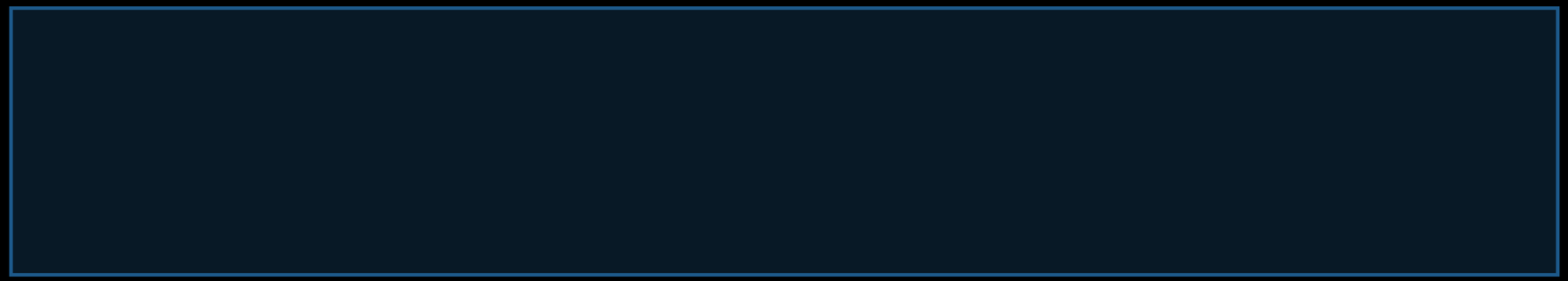

Protocol Extensions

Requirements create customization points

```
extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

Protocol Extensions

Requirements create customization points

```
extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
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```

Protocol Extensions

Requirements create customization points

```
extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
let r = TestRenderer()
r.circleAt(origin, radius: 1);
r.rectangleAt(edges);
```

Protocol Extensions

Requirements create customization points

```
extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
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  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
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  func rectangleAt(edges: CGRect) { ... }
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  func circleAt(center: CGPoint, radius: CGFloat) { ... }
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  func circleAt(center: CGPoint, radius: CGFloat) { ... }
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r.circleAt(origin, radius: 1);
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```

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  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}

let r: Renderer = TestRenderer()
r.circleAt(origin, radius: 1);
r.rectangleAt(edges);
```

Provides the requirement

Protocol Extensions

Requirements create customization points

```
extension Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
}
```

```
extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }
  func rectangleAt(edges: CGRect) { ... }
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let r: Renderer = TestRenderer()
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Protocol Extensions

Requirements create customization points

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extension Renderer {
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  func circleAt(center: CGPoint, radius: CGFloat) { ... }
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let r: Renderer = TestRenderer()
r.circleAt(origin, radius: 1);
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Protocol Extensions

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extension TestRenderer : Renderer {
  func circleAt(center: CGPoint, radius: CGFloat) { ... }

}

let r: Renderer = TestRenderer()
r.circleAt(origin, radius: 1);
r.rectangleAt(edges);
```

More Protocol Extension Tricks

Scenes from the standard library and beyond

More Protocol Extension Tricks

Constrained extensions

```
extension CollectionType {
  public func indexOf(element: Generator.Element) -> Index? {
    for i in self.indices {
      if self[i] == element {
        return i
      }
    }
    return nil
  }
}
```

More Protocol Extension Tricks

Constrained extensions

```
extension CollectionType {
  public func indexOf(element: Generator.Element) -> Index? {
    for i in self.indices {
      if self[i] == element {
        return i
      }
    }
    return nil
  }
}
```

binary operator '==' cannot be applied to two Generator.Element operands

More Protocol Extension Tricks

Constrained extensions

```
extension CollectionType {
  public func indexOf(element: Generator.Element) -> Index? {
    for i in self.indices {
      if self[i] == element {
        return i
      }
    }
    return nil
  }
}
```

binary operator '==' cannot be applied to two Generator.Element operands

More Protocol Extension Tricks

Constrained extensions

NEW

```
extension CollectionType where Generator.Element : Equatable {
  public func indexOf(element: Generator.Element) -> Index? {
    for i in self.indices {
      if self[i] == element {
        return i
      }
    }
    return nil
  }
}
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
let position = binarySearch([2, 3, 5, 7], forKey: 5)
```

More Protocol Extension Tricks

Retroactive adaptation

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protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
let position = binarySearch([2, 3, 5, 7], forKey: 5)
```

cannot invoke 'binarySearch' with an argument list of type '([Int], forKey: Int)'

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Int : Ordered {
  func precedes(other: Int) -> Bool { return self < other }
}
```

```
let position = binarySearch([2, 3, 5, 7], forKey: 5)
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Int : Ordered {
  func precedes(other: Int) -> Bool { return self < other }
}
```

```
let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Int : Ordered {
  func precedes(other: Int) -> Bool { return self < other }
}
```

cannot invoke 'binarySearch' with an argument list of type '([String], forKey: String)'

```
let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Int : Ordered {
  func precedes(other: Int) -> Bool { return self < other }
}
extension String : Ordered {
  func precedes(other: String) -> Bool { return self < other }
}

let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}


let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
extension Double : Ordered {}

let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}


let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)   // Compiles

let position = binarySearch(["2", "3", "5", "7"], forKey: "5")
```

More Protocol Extension Tricks

Retroactive adaptation

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protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
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extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)   // Compiles

let position = binarySearch([2.0, 3.0, 5.0, 7.0], forKey: 5.0)
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)   // Compiles

let position = binarySearch([2.0, 3.0, 5.0, 7.0], forKey: 5.0)
```

cannot invoke 'binarySearch' with an argument list of type '([Double], forKey: Double)'

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)   // Compiles
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Ordered where Self : Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)
```

More Protocol Extension Tricks

Retroactive adaptation

```
protocol Ordered {
  func precedes(other: Self) -> Bool
}
func binarySearch<T : Ordered>(sortedKeys: [T], forKey k: T) -> Int { ... }
```

```
extension Ordered where Self : Comparable {
  func precedes(other: Self) -> Bool { return self < other }
}
extension Int : Ordered {}
extension String : Ordered {}
let truth = 3.14.precedes(98.6)
```

'Double' does not have a member named 'precedes'

More Protocol Extension Tricks

Generic beautification

```
func binarySearch<
  C : CollectionType where C.Index == RandomAccessIndexType,
  C.Generator.Element : Ordered
>(sortedKeys: C, forKey k: C.Generator.Element) -> Int {
  ...
}

let pos = binarySearch([2, 3, 5, 7, 11, 13, 17], forKey: 5)
```

More Protocol Extension Tricks

Generic beautification

```
extension CollectionType where Index == RandomAccessIndexType,
Generator.Element : Ordered {

  func binarySearch(forKey: Generator.Element) -> Int {
    ...
  }

}

let pos = [2, 3, 5, 7, 11, 13, 17].binarySearch(5)
```

More Protocol Extension Tricks

Generic beautification

```
extension CollectionType where Index == RandomAccessIndexType,
Generator.Element : Ordered {

  func binarySearch(forKey: Generator.Element) -> Int {
    ...
  }

}

let pos = [2, 3, 5, 7, 11, 13, 17].binarySearch(5)
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extension CollectionType where Index == RandomAccessIndexType,
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let pos = [2, 3, 5, 7, 11, 13, 17].binarySearch(5)
```

More Protocol Extension Tricks

Generic beautification

```
extension CollectionType where Index == RandomAccessIndexType,
Generator.Element : Ordered {

  func binarySearch(forKey: Generator.Element) -> Int {
    ...
  }

}

let pos = [2, 3, 5, 7, 11, 13, 17].binarySearch(5)
```

More Protocol Extension Tricks

Interface generation

NEW

More Protocol Extension Tricks

Interface generation

NEW

Make All Value Types `Equatable`

```
func == (lhs: Polygon, rhs: Polygon) -> Bool {
  return lhs.corners == rhs.corners
}
extension Polygon : Equatable {}
```

```
func == (lhs: Circle, rhs: Circle) -> Bool {
  return lhs.center == rhs.center
    && lhs.radius == rhs.radius
}
extension Circle : Equatable {}
```

Make All Value Types `Equatable`

```
func == (lhs: Polygon, rhs: Polygon) -> Bool {
  return lhs.corners == rhs.corners
}
extension Polygon : Equatable {}
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```
func == (lhs: Circle, rhs: Circle) -> Bool {
  return lhs.center == rhs.center
    && lhs.radius == rhs.radius
}
extension Circle : Equatable {}
```

Make All Value Types `Equatable`

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
  return lhs.elements == rhs.elements
}
```

Make All Value Types `Equatable`

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
  return lhs.elements == rhs.elements
}
```

binary operator '==' cannot be applied to two [Drawable] operands.

Make All Value Types `Equatable`

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
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Make All Value Types `Equatable`

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struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
  return lhs.elements.count == rhs.elements.count
    && !zip(lhs.elements, rhs.elements).contains { $0 != $1 }
}
```

Make All Value Types `Equatable`

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
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func == (lhs: Diagram, rhs: Diagram) -> Bool {
  return lhs.elements.count == rhs.elements.count
    && !zip(lhs.elements, rhs.elements).contains { $0 != $1 }
}
```

binary operator '!=' cannot be applied to two Drawable operands.

Make All Value Types `Equatable`

```
struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
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```

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func == (lhs: Diagram, rhs: Diagram) -> Bool {
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Should Every `Drawable` Be `Equatable`?

```
struct Diagram : Drawable {
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protocol Drawable : Equatable {
  func draw()
}
```

Should Every `Drawable` Be `Equatable`?

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struct Diagram : Drawable {
  func draw(renderer: Renderer) { ... }
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}
```

```
protocol Equatable {
  func == (Self, Self) -> Bool
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
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Should Every `Drawable` Be `Equatable`?

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struct Diagram : Drawable {
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func == (lhs: Diagram, rhs: Diagram) -> Bool {
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    && !zip(lhs.elements, rhs.elements).contains { $0 != $1 }
}
```

```
protocol Drawable : Equatable {
  func draw()
}
```

Bridge-Building

```
struct Diagram : Drawable, Equatable {
  func draw(renderer: Renderer) { ... }
  var elements: [Drawable] = []
}
```

```
func == (lhs: Diagram, rhs: Diagram) -> Bool {
  return lhs.elements.count == rhs.elements.count
    && !zip(lhs.elements, rhs.elements).contains { !$0.isEqualTo($1) }
}

protocol Drawable {
  func isEqualTo(other: Drawable) -> Bool
  func draw()
}
```

Bridge-Building

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struct Diagram : Drawable {
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protocol Drawable {
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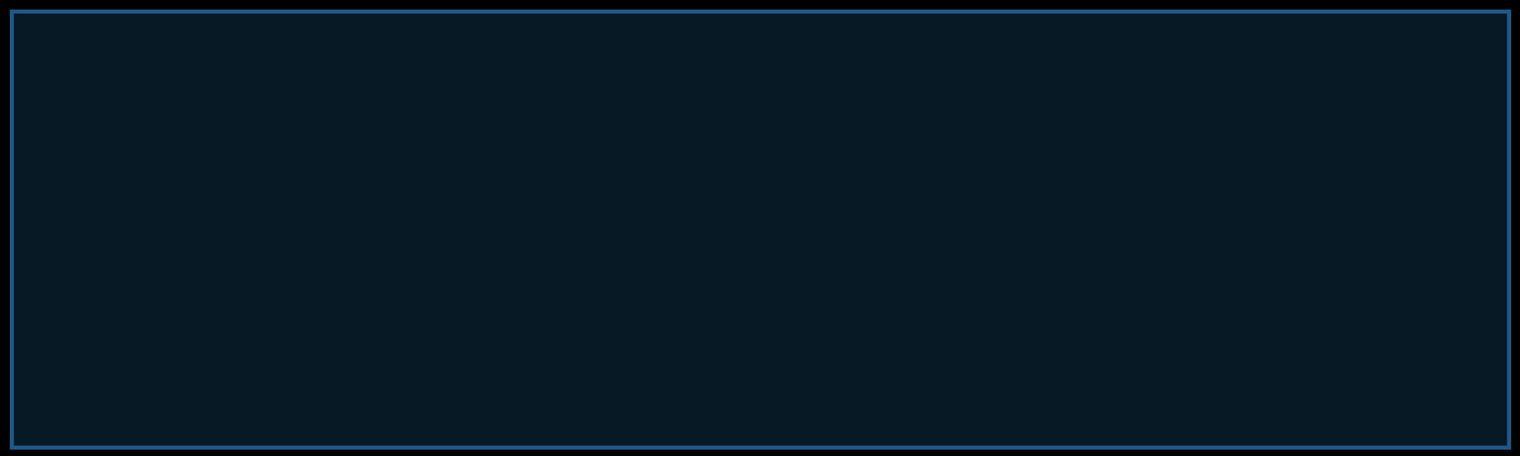

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protocol Drawable {
  func isEqualTo(other: Drawable) -> Bool
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}
extension Drawable where Self : Equatable {
  func isEqualTo(other: Drawable) -> Bool {
    if let o = other as? Self { return self == o }
    return false
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Bridge-Building

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  func isEqualTo(other: Drawable) -> Bool {
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    return false
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```

When to Use Classes

They do have their place…

You *want* implicit sharing when

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- Instance lifetime is tied to external effects (e.g., TemporaryFile)
- Instances are just "sinks"—write-only conduits to external state (e.g., CGContext)

```
final class StringRenderer : Renderer {
  var result: String
  ...
}
```

When to Use Classes

They do have their place…

You *want* implicit sharing when

- Copying or comparing instances doesn't make sense (e.g., Window)
- Instance lifetime is tied to external effects (e.g., TemporaryFile)
- Instances are just "sinks"—write-only conduits to external state (e.g., CGContext)

```
final class StringRenderer : Renderer {
  var result: String
  ...
}
```

Still a protocol!

When to Use Classes

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Don't fight the system

- If a framework expects you to subclass, or to pass an object, do!

When to Use Classes

They do have their place…

Don't fight the system

- If a framework expects you to subclass, or to pass an object, do!

On the other hand, be circumspect

- Nothing in software should grow too large
- When factoring something out of a class, consider a non-class

Summary

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Protocols > Superclasses

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Protocol extensions = magic (almost)

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Go see the value types talk on Friday!

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Eat your vegetables

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Protocols > Superclasses

Protocol extensions = magic (almost)

Go see the value types talk on Friday!

Eat your vegetables

Be like Crusty…

Think different.

More Information

Swift Language Documentation
http://developer.apple.com/swift

Apple Developer Forums
http://developer.apple.com/forums

Stefan Lesser
Swift Evangelist
slesser@apple.com

Related Sessions

Building Better Apps with Value Types in Swift	Mission	Friday 2:30PM

WWDC15