Functional programming in Swift

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Functional Programming in Swift

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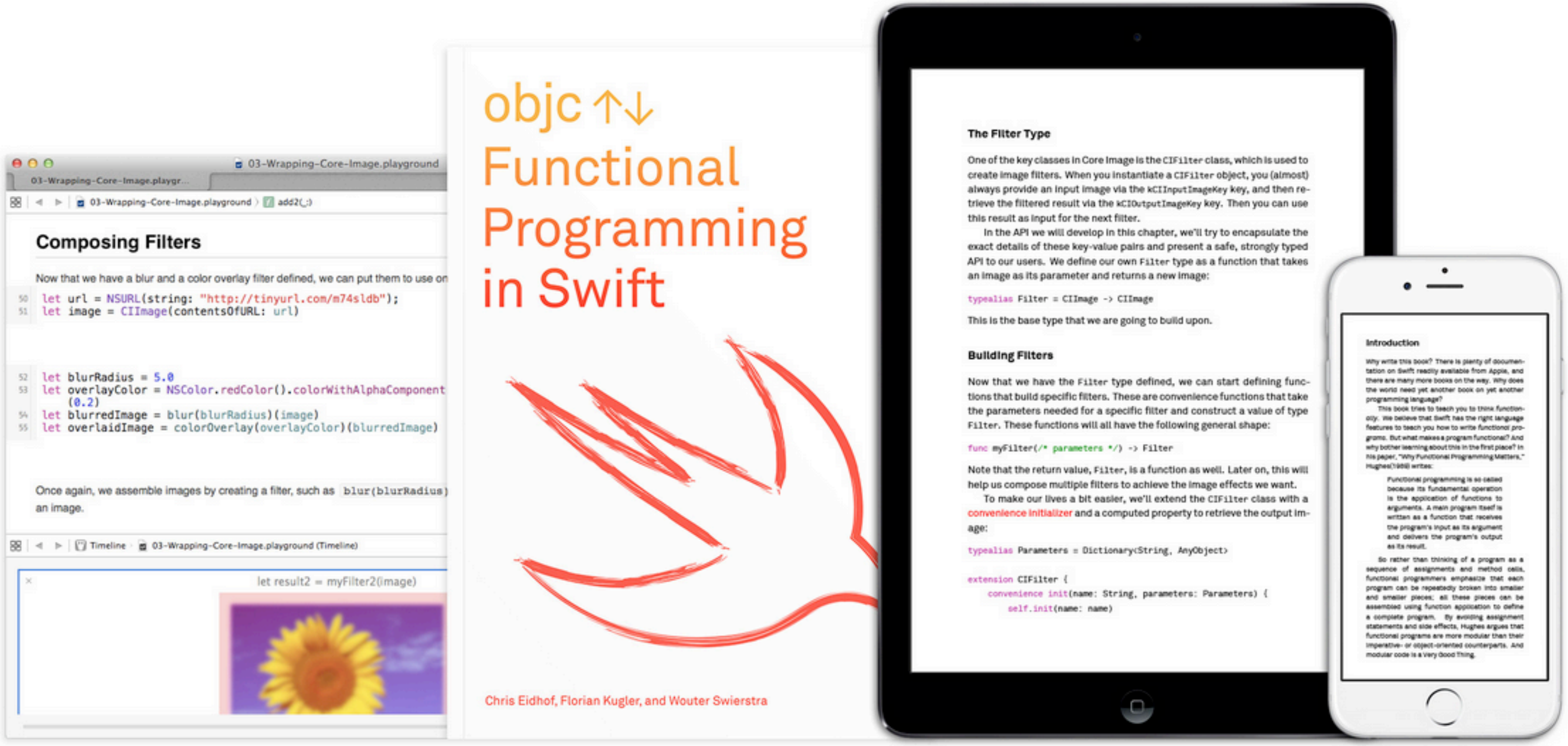


What kind of language is Swift?

It’s like Objective-C, without the C.

— *Craig Federighi, WWDC*

"Objective-C without the C" implies something subtractive, but Swift dramatically expands the design space through the introduction of generics and functional programming concepts.

– Chris Lattner, Apple Developer Forums

What is functional programming?

Maps and filters

Many people describe functional programming as being about `map`, `filter` and `reduce`:

```
[1,2,3].map({x in x + 1})
```

These are examples of functions drawn from FP.

But this is like saying object oriented programming is about Shapes and Animals.

Characteristics of FP

- Modularity
- Effective usage of types
- Careful treatment of state and effects

What you will learn

The aim of this talk is not to teach you Swift...

... or the frameworks and IDE for iOS and OS X development.

But rather showcase *how* you can use some of the ideas from functional programming in your projects.

Core Image

San Francisco

The challenge

The Core Image API is a bit clunky.

```
CIFilter *hueAdjust = [CIFilter filterWithName:@"CIHueAdjust"];
[hueAdjust setDefaults];
[hueAdjust setValue: myCIImage forKey: kCIInputImageKey];
[hueAdjust setValue: @2.094f forKey: kCIInputAngleKey];
```

The resulting image after running the filter can be retrieved from the `kCIOutputImageKey`.

The challenge

The Core Image API has some drawbacks:

- It's easy to forget to set some parameters (or set the wrong parameters) – causing a run-time crash;
- Not type safe – you can set the wrong type of value for some key, which again causes a run-time crash;
- Not modular – there's no easy way to compose two filters.

A functional solution

```
typealias Filter = CIImage -> CIImage
```

A filter is a function that transforms an image.

A trivial filter

```
func noFilter() -> Filter {
    return {image in return image}
}
```

This filter does nothing, and returns the input image.

An example filter

```
func blur(radius: Double) -> Filter {
    return {image in
        let parameters : Parameters =
           [kCIInputRadiusKey: radius, kCIInputImageKey: image]
        // Here we're calling a convenience initializer
        // that sets certain defaults
        let blurFilter = CIFilter(name:"CIGaussianBlur",
                                  parameters:parameters)
        return blurFilter.outputImage
    }
}
```

Calling this filter

```
let url = NSURL(string: "http://tinyurl.com/sfswift")
let image : CIImage = CIImage(contentsOfURL: url)

let blurBy5 : Filter = blur(5)
let blurred : CIImage = blurBy5(image)
```

Other filters

```
func compositeSourceOver(overlay: CIImage) -> Filter {
...
}

func colorGenerator(color: NSColor) -> Filter {
...
}

func colorOverlay(color: NSColor) -> Filter {
...
}
```

Filtering more than once

```
let img : CIImage = ...
let blurRadius = 5.0
let overlayColor = NSColor.whiteColor().colorWithAlphaComponent(0.2)
let blurredImage = blur(blurRadius)(image)
let overlaidImage = colorOverlay(overlayColor)(blurredImage)
```

How can we compose filters?

Composing filters – function composition

```
func composeFilters(filter1: Filter, filter2: Filter) -> Filter {
    return {img in filter2(filter1(img)) }
}

let img = ...
let compositeFilter = compose(blur(blurRadius),
                              colorOverlay(overlayColor))

let filteredImg = compositeFilter(img)
```

A composition operator

```
infix operator >>> { associativity left }

func >>> (filter1: Filter, filter2: Filter) -> Filter {
    return {img in filter2(filter1(img))}
}

let myFilter = blur(blurRadius) >>> colorOverlay(overlayColor)
```

We can now chain together filters, similarly to Unix pipes.

Taking stock

We have a wrapper around a fragment of Core Image that is both **type-safe** and **modular**.

Using higher-order functions (similar to Objective-C's *blocks*)...

... but there are alternative definitions that have the same compositional behaviour, that are entirely first-order.

Enumerations

Enumerations in Objective C

Enumerations are thin wrapper around a collection of integer constants:

```
enum NSStringEncoding {
    NSASCIIStringEncoding = 1,
    NSNEXTSTEPStringEncoding = 2,
    NSJapaneseEUCStringEncoding = 3,
    NSUTF8StringEncoding = 4,
// ...
}
```

Enumerations in Objective C

Why should such expressions make sense?

```
if (NSASCIIStringEncoding + NSNEXTSTEPStringEncoding
  == NSJapaneseEUCStringEncoding) {...
}
```

Enumerations in Swift

In Swift on the other hand, enumerations:

- introduce a new type, separate from the underlying integers;
- may have associated values;
- can be decomposed by pattern matching.

Reading a file – Obj C

The **type** of the `NSString` initializer isn't helpful.

```
+ (instancetype)stringWithContentsOfFile:(NSString *)path
                                encoding:(NSStringEncoding)enc
                                   error:(NSError **)error
```

To check for errors, do I inspect the `error` or the return value?

Reading a file – Swift

```
func readFile(path: String, encoding: NSStringEncoding) -> String? {
    var maybeError: NSError? = nil
    return NSString(contentsOfFile: path,
                    encoding: encoding,
                    error: &maybeError)
}
```

The type is telling us more, but we can't get our hands on the `NSError` when the function fails.

Enumerations

```
enum Result {
    case Success(String)
    case Failure(NSError)
}
```

A value of type `Result` is tagged as being either:

- `Success` – in which case we have the file contents;
- `Failure` – in which case we have an `NSError`.

readFile revisited

```
func readFile(path: String, encoding: NSStringEncoding) -> Result {
    var maybeError: NSError?
    let maybeString: String? = NSString(contentsOfFile: path,
                                        encoding: encoding,
                                        error: &maybeError)
    if let string = maybeString {
        return Result.Success(string)
    } else {
        return Result.Failure(maybeError!)
    }
}
```

Reading a file

```
switch readFile("README.md", NSASCIIStringEncoding) {
    case let Result.Success(contents):
        // Process file contents
        ...
    case let Result.Failure(error):
        // Handle error
        ...
}
```

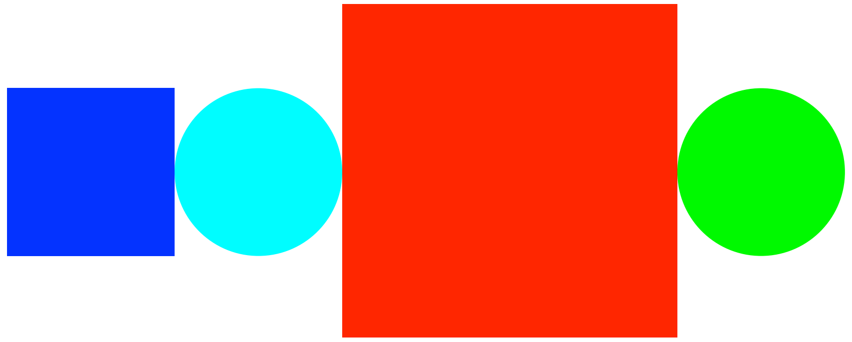
Diagrams in Swift

Diagrams in Objective C

```
NSColor.blueColor().setFill()
CGContextFillRect(context, CGRectMake(0.0, 37.5, 75.0, 75.0))
NSColor.redColor().setFill()
CGContextFillRect(context, CGRectMake(75.0, 0.0, 150.0, 150.0))
NSColor.greenColor().setFill()
CGContextFillEllipseInRect(context,
                           CGRectMake(225.0, 37.5, 75.0, 75.0))
```

Diagrams in Objective C

But what if I want to draw this:



Instead of this:

Diagrams in Objective C

The drawing commands are non-compositional:

- They have hard-coded coordinates;
- They focus on *how* things should be drawn rather than *what* should be drawn;
- Any changes to a sub-drawing require rewriting the complete code.

A functional solution...

Instead of drawing commands directly, we'll design a *domain specific language* for diagram descriptions.

1. Define an enumeration that describes diagrams

2. 'Interpret' this description using a Core Graphics

Intended solution

```
let blueSquare = square(side: 1).fill(NSColor.blueColor())
let redSquare = square(side: 2).fill(NSColor.redColor())
let greenCircle = circle(radius: 1).fill(NSColor.greenColor())
let example1 = blueSquare ||| redSquare ||| greenCircle
```

Intended solution

Adding new shapes is easy:

```
let cyanCircle = circle(radius: 1).fill(NSColor.cyanColor())
let example2 = blueSquare ||| cyanCircle |||
               redSquare ||| greenCircle
```

This solution is *compositional*

Diagrams in Swift[1]

```
enum Primitive {
    case Ellipse
    case Rectangle
    case Text(String)
}

enum Diagram {
    case Prim(CGSize, Primitive)
    case Beside(Diagram, Diagram)
    case Below(Diagram, Diagram)
    case Attributed(Attribute, Diagram)
    case Align(Vector2D, Diagram)
}
```

[1] Recursive enumerations need a workaround

Example: computing the size

```
extension Diagram {
    var size: CGSize {
        switch self {
        case let .Prim(size, _):
            return size
        case let .Attributed(_, x):
            return x.size
        case let .Beside(l, r):
            let sizeL = l.size
            let sizeR = r.size
            return CGSizeMake(sizeL.width + sizeR.width,
                              max(sizeL.height, sizeR.height))
    ...
```

Drawing a diagram

```
func draw(context: CGContextRef, bounds: CGRect, diagram: Diagram) {
    switch diagram {
        case let .Prim(size, .Ellipse):
            let frame = fit(defaultAlign, size, bounds)
            CGContextFillEllipseInRect(context, frame)

// And similar cases for drawing text and squares
```

Drawing composite diagrams

```
func draw(context: CGContextRef, bounds: CGRect, diagram: Diagram) {
    switch diagram {
    ...
    case let .Beside(left, right):
            let (lFrame, rFrame) =
                splitHorizontal(bounds, left.size/diagram.size)
            draw(context, lFrame, left)
            draw(context, rFrame, right)
```

A few more cases for vertical composition, alignment, etc.

Building a more complete library

On top of this we can define *combinators* to make it easier to define complex diagrams:

```
func square(side: CGFloat) -> Diagram {
    return rect(width: side, height: side)
}

infix operator ||| { associativity left }
func ||| (l: Diagram, r: Diagram) -> Diagram {
    return Diagram.Beside(l,r)
}

infix operator --- { associativity left }
func --- (l: Diagram, r: Diagram) -> Diagram {
    return Diagram.Below(l,r)
}
```

Adding attributes or alignment

```swift
extension Diagram {
    func fill(color: NSColor) -> Diagram {
        return Diagram.Attributed(Attribute.FillColor(color), self)
    }

    func alignTop() -> Diagram {
        return Diagram.Align(Vector2D(x: 0.5, y: 1), self)
    }
}
```

So we can now write:

```swift
let redSquare = square(side: 2).fill(NSColor.redColor())
let greenCircle = circle(radius: 1).fill(NSColor.greenColor())
let example1 = greenCircle.alignTop() ||| redSquare
```

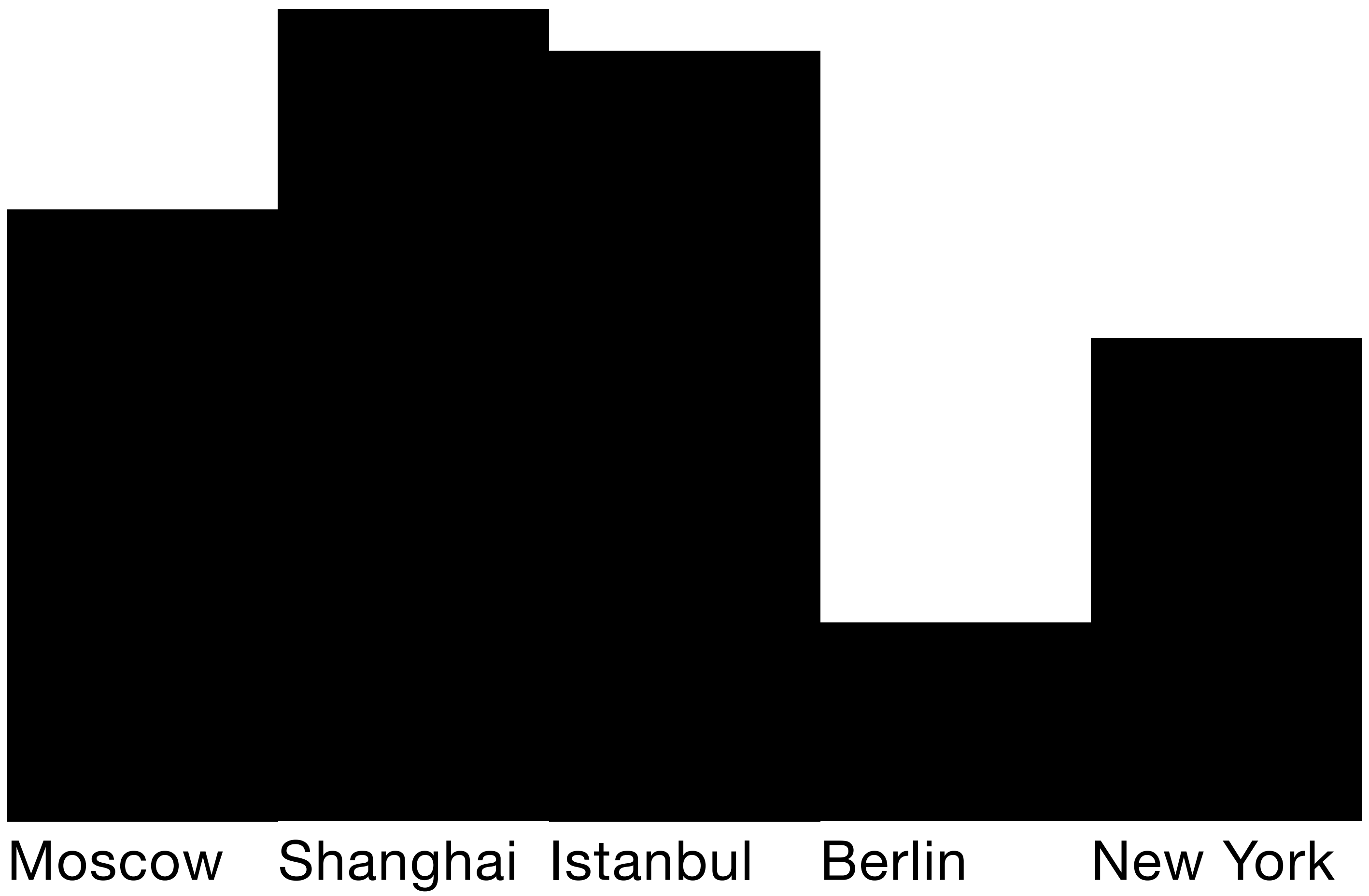
Combining lists of diagrams

```
let empty: Diagram = rect(width: 0, height: 0)

func hcat(diagrams: [Diagram]) -> Diagram {
    return diagrams.reduce(empty, |||)
}
```

Example: visualizing dictionaries

```
let cities = ["Moscow": 10.56, "Shanghai": 14.01, "Istanbul": 13.3,
              "Berlin": 3.43, "New York": 8.33]
```



Generating bar graphs

```
func barGraph(input: [(String, Double)]) -> Diagram {
    let normalizedValues : [CGFloat] = normalize(input)
    let bars = hcat(normalizedValues.map { x in
        rect(width: 1, height: 3 * x)
        .fill(NSColor.blackColor())
        .alignBottom()
    })
    let labels = hcat(input.map { x in
        text(width: 1, height: 0.3, text: x.0)
        .alignTop()
    })
    return bars --- labels
}
```

Diagrams

- A compositional language for defining simple diagrams
- Easy to extend with new combinators
- Separates the *what* from the *how*
- The same techniques can be used in other programming languages, but they feel more natural in Swift.

Things I haven't talked about

- Generics & protocols
- Reference types versus value types
- Sequences & generators
- QuickCheck & testing functional code
- Currying, parser combinators, type-level programming...

The future of Swift

Apple is starting to actively push Swift...

Swift offers developers both a great *platform* and a great *language*

Learning more

- Lots of Apple documentation
- Swift tutorial today
- Functional Swift Conference
- obj.io – Issue 16
- Summer School on Applied Functional Programming in Utrecht.

Questions?