The SwiftUI Lab

When the documentation is missing, we experiment.

Menu

Advanced SwiftUI Animations – Part 1: Paths

August 26, 2019 by javier

In this article we are going to dive into some advanced techniques to create SwiftUI animations. I will talk extensively about the Animatable protocol, its trusty companion animatableData, the powerful and often ignored GeometryEffect and the completely overlooked but almighty AnimatableModifier protocol.

These are all topics that have been totally ignored by the official documentation, and hardly ever mention in SwiftUI posts and articles. Still, they provide us with the tools to create some pretty nice animations.

Before we get into these hidden gems, I want to make a **very** quick summary on some basic SwiftUI animation concepts. Just so that we are all in the same page. Please bear with me.

> **The complete sample code for this article can be found at:**
> https://gist.github.com/swiftui-lab/e5901123101ffad6d39020cc7a810798
>
> **Example**8 requires images from an Asset catalog. Download it from here:
> https://swiftui-lab.com/?smd_process_download=1&download_id=916

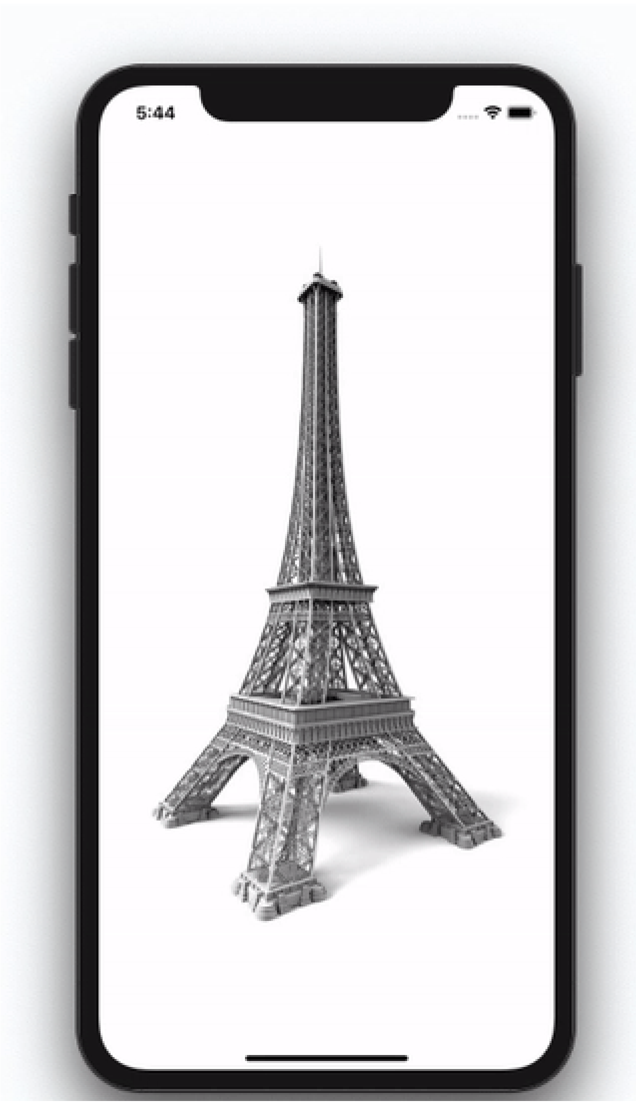
Explicit vs. Implicit Animations

There are two typ

with the `.animation()` modifier. Whenever a animatable parameter is changed on a view, SwiftUI will animate from the old to the new value. Some animatable parameters are size, offset, color, scale, etc.

Explicit animations are those specified with a `withAnimation { ... }` closure. Only those parameters that depend on a value changed inside the withAnimation closure will be animated. Let’s try some examples to illustrate:

The following example uses implicit animations to alter the size and opacity of an image:



Implicit Animation

```
struct Example1: View {
    @State private var half = false
    @State private var dim = false

    var body: some View {
        Image("tower")
            .scaleEffect(half ? 0.5 : 1.0)
            .opacity(dim ? 0.2 : 1.0)
            .
            .
                self.dim.toggle()
```

```
                    self.half.toggle()
                }
            }
    }
```

The following example uses explicit animations. Here, both scale and opacity are changed, but only opacity will be animated, as it is the only parameter altered inside the `withAnimation` closure:

Explicit Animation

```
struct Example2: View {
    @State private var half = false
    @State private var dim = false

    var body: some View {
        Image("tower")
            .scaleEffect(half ? 0.5 : 1.0)
            .opacity(dim ? 0.5 : 1.0)
```

```
                withAnimation(.easeInOut(duration: 1.0)) {
                    self.dim.toggle()
                }
            }
        }
    }
```

Note that you can create the same result, using implicit animations, by altering the order in which modifiers are placed:

```
struct Example2: View {
    @State private var half = false
    @State private var dim = false

    var body: some View {
        Image("tower")
            .opacity(dim ? 0.2 : 1.0)
            .animation(.easeInOut(duration: 1.0))
            .scaleEffect(half ? 0.5 : 1.0)
            .onTapGesture {
                self.dim.toggle()
                self.half.toggle()
        }
    }
}
```

Should you ever need to disable an animation, you may use `.animation(nil)`.

How Do Animations Work

Behind all SwiftUI animations, there's a protocol named `<strong>Animatable</strong>`. We will go into the details later, but mainly, it involves having a computed property with a type that conforms to `VectorArithmetic`. This makes it possible for the framework to interpolate values at will.

When animating a view, SwiftUI is really regenerating the view many times, and each time modifying the animating parameter. This way it goes progressively from the origin value to the final value.

Suppose we create a linear animation for the opacity of a view. We intend to go from 0.3 to 0.8. The framework will regenerate the view many times, altering the opacity by little increments. Since opacity is expressed as a `Double`, and because `Double` conforms to `VectorArithmetic`, SwiftUI can interpolate the opacity values required. Somewhere in the framework's code, there's probably an algorithm like this:

```
let from:Double = 0.3
let to:Double = 0.8

for i in 0..<6 {
    let pct = Double(i) / 5

    var diffe
    difference.scale(by: pct)
```

```
    let currentOpacity = from + difference

    print("currentOpacity = \(currentOpacity)")
}
```

The code will create progressive changes from origin to destination:

```
currentOpacity = 0.3
currentOpacity = 0.4
currentOpacity = 0.5
currentOpacity = 0.6
currentOpacity = 0.7
currentOpacity = 0.8
```

Why Do I Care About Animatable?

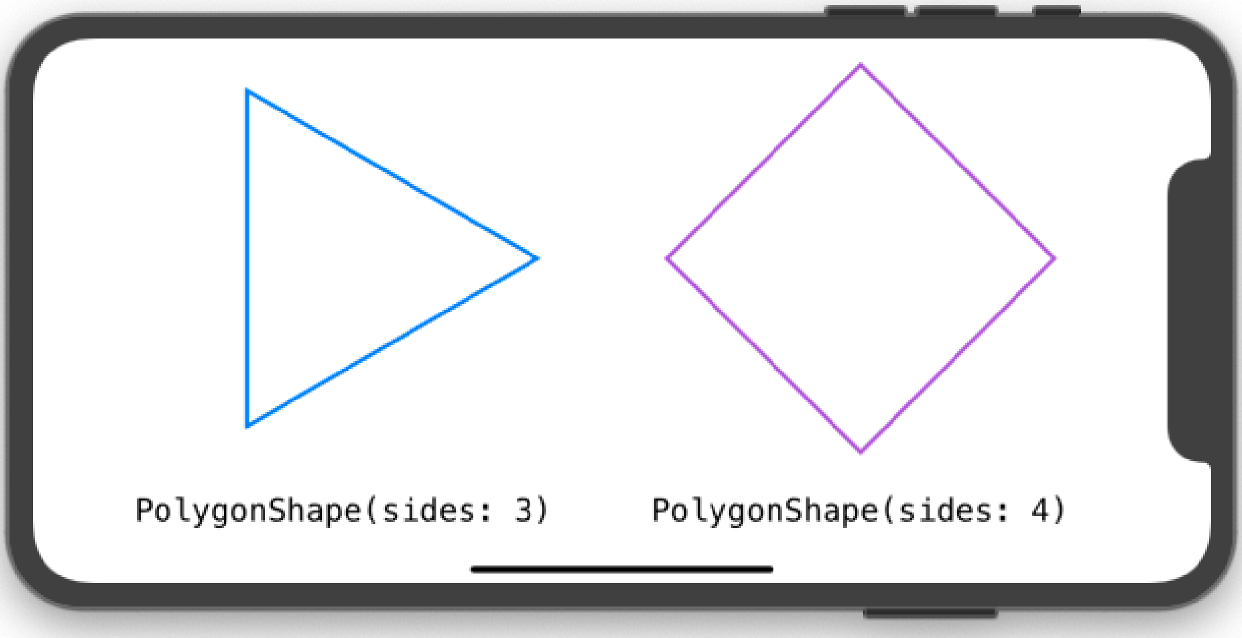
You may wonder, why do I need to care about all these little details. SwiftUI already animates opacity, without me having to worry about all this. And yes, that is true, but as long as SwiftUI knows how to interpolate values from an origin to a destination. For opacity, it is a straight forward process and SwiftUI knows what to do. However, as we will see next, that is not always the case.

There are some big exceptions that come to mind: paths, transform matrices and arbitrary view changes (e.g, the text in a Text view, the gradient colors or stops in a Gradient, etc.). In this cases, the framework does not know what to do. There is no predefined behavior on how to get from A to B. We will discuss transform matrices and view changes, in the upcoming second and third part of this article. For the moment, let's focus on shapes.

Animating Shape Paths

Imagine you have a shape that uses a path to draw a regular polygon. Our implementation will of course let you indicate how many sides the polygon will have:

```
PolygonShape(sides: 3).stroke(Color.blue, lineWidth: 3)
PolygonShape(sides: 4).stroke(Color.purple, lineWidth: 4)
```



Here's our PolygonShape implementation. Notice that I used a little bit of trigonometry. It is not essential to understand the topic of this post, but if you would like to learn more about it, I wrote another article laying out the basics. You can read more in "Trigonometric Recipes for SwiftUI".

```
struct PolygonShape: Shape {
    var sides: Int

    func path(in rect: CGRect) -> Path {
        // hypotenuse
        let h = Double(min(rect.size.width, rect.size.height)) / 2.0

        // center
        let c = CGPoint(x: rect.size.width / 2.0, y: rect.size.height / 2.0)

        var path = Path()

        for i in 0..<sides {
            let angle = (Double(i) * (360.0 / Double(sides))) * Double.pi / 180

            // Calculate vertex position
            let pt = CGPoint(x: c.x + CGFloat(cos(angle) * h), y: c.y + CGFloat(sin(angle) * h))

            if i == 0 {
                path.move(to: pt) // move to first vertex
            } else {
                path.addLine(to: pt) // draw line to next vertex
            }
        }

        path.

        return path
```

```
    }
}
```

We could take it a little further, and try to animate the side parameter using the same method we used with opacity:

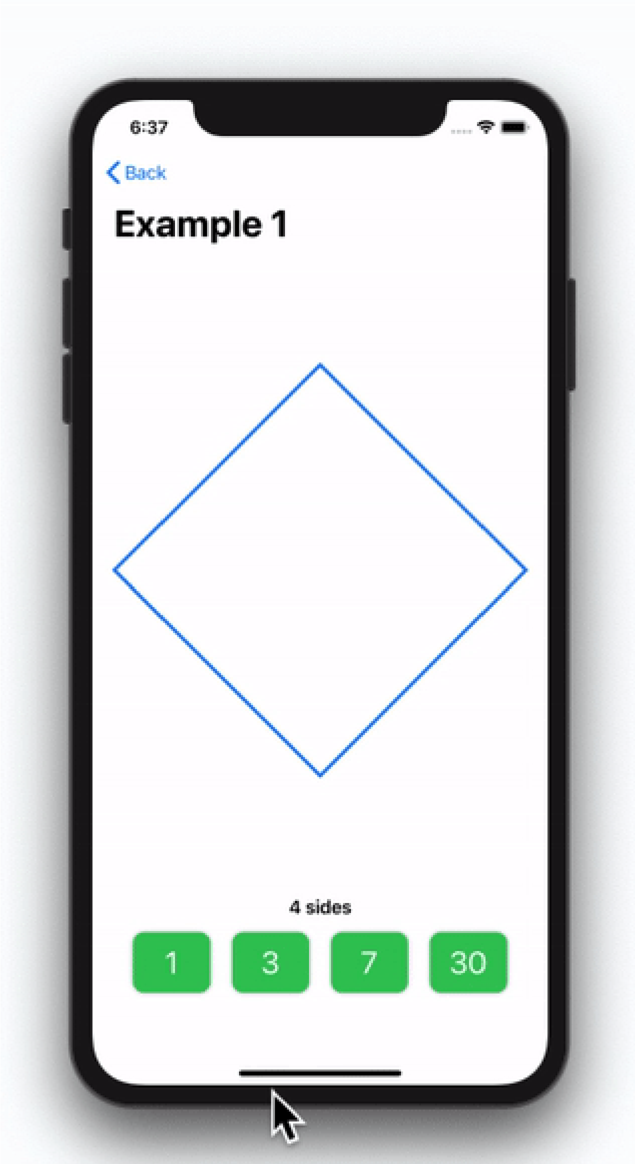
```
PolygonShape(sides: isSquare ? 4 : 3)
    .stroke(Color.blue, lineWidth: 3)
    .animation(.easeInOut(duration: duration))
```

How do you think SwiftUI will transform the triangle into a square? You probably guessed it. It won't. Of course the framework has no idea how to animate it. You may use .animation() all you want, but the shape will jump from a triangle to a square with no animation. The reason is simple: you only taught SwiftUI how to draw a 3-sided polygon, or 4-sided polygon, but you code does not know how to draw a 3.379-sided polygon!

So, for the animation to happen, we need two things:

1. We need to alter the shape code, so it knows how to draw a polygon with a non-integer `sides` number.
2. Make the framework generate the shape multiple times, with little increments in the animatable parameter. That is, we want the shape be asked to draw multiple times, each time with a different value for the `sides` parameter: 3, 3.1, 3.15, 3.2, 3.25, all the way to 4.

Once we put that in place, we will be able to animate between any number of sides:



Generating Animatable Data

To make the shape animatable, we need SwiftUI to render the view multiple times, using all the side values between the origin to the destination number. Fortunately, Shape already conforms to the `Animatable` protocol. This means, there is a computed property (`animatableData`), that we can use to handle this task. Its default implementation, however, is set to `EmptyAnimatableData`. So it does nothing.

To solve our problem, we will start by changing the type of the sides property, from `Int` to `Double`. This way we can have decimal numbers. We will discuss later how we can maintain the property as `Int` and still perform the animation. But for the moment, to keep things simple, let's just use `Double`.

```
struct PolygonShape: Shape {
    var sides: Double
    ...
}
```


Then, we need to

```
struct PolygonShape: Shape {
    var sides: Double

    var animatableData: Double {
        get { return sides }
        set { sides = newValue }
    }

    ...
}
```

Drawing Sides with a Decimal Number

Finally, we need to teach SwiftUI how to draw a polygon with a non-integer number of sides. We will slightly alter our code. As the decimal part grows, this new side will go from zero to its full length. The other vertices will smoothly reposition accordingly. It sounds complicated, but it is a minimal change:

```
func path(in rect: CGRect) -> Path {

        // hypotenuse
        let h = Double(min(rect.size.width, rect.size.height)) / 2.0

        // center
        let c = CGPoint(x: rect.size.width / 2.0, y: rect.size.height / 2.0)

        var path = Path()

        let extra: Int = Double(sides) != Double(Int(sides)) ? 1 : 0

        for i in 0..<Int(sides) + extra {
            let angle = (Double(i) * (360.0 / Double(sides))) * Double.pi / 180

            // Calculate vertex
            let pt = CGPoint(x: c.x + CGFloat(cos(angle) * h), y: c.y + CGFloat(sin(angle) * h))

            if i == 0 {
                path.move(to: pt) // move to first vertex
            } else {
                path.addLine(to: pt) // draw line to next vertex
            }
        }

        path.closeSubpath()

        return path
    }
```

The complete code is available as *Example1*, in the gist file linked at the top the article.

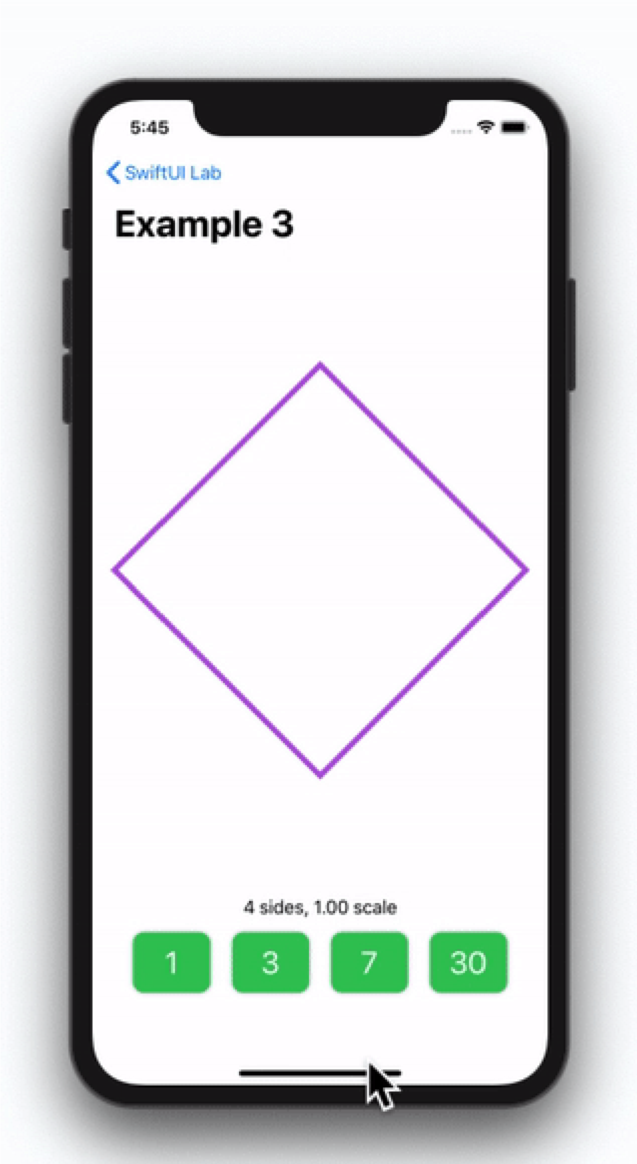
As mentioned ea
should expect si
inside our shape's implementation:

```
struct PolygonShape: Shape {
    var sides: Int
    private var sidesAsDouble: Double

    var animatableData: Double {
        get { return sidesAsDouble }
        set { sidesAsDouble = newValue }
    }

    init(sides: Int) {
        self.sides = sides
        self.sidesAsDouble = Double(sides)
    }

    ...
}
```

With these changes, we internally use a `Double`, but externally we use an `Int`. It looks much more elegant now. And do not forget to modify the drawing code, so it uses `sidesAsDouble` instead of `sides`. The complete code is available as ***Example2***, in the gist file linked at the top of the article.

Animating More Than One Parameter

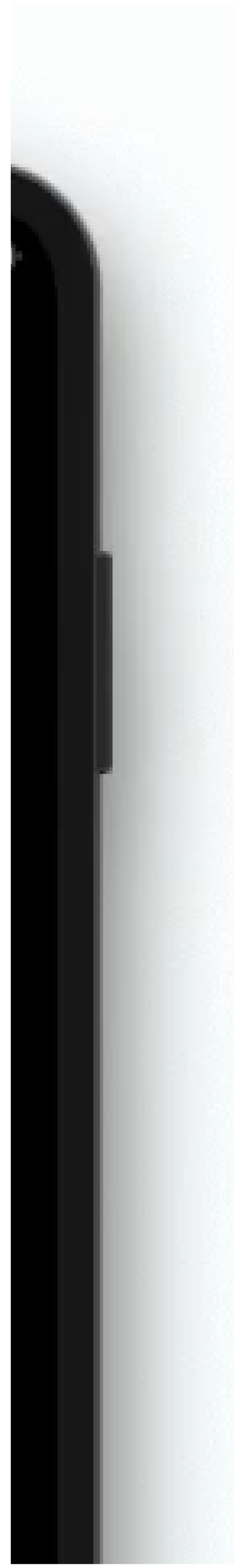
Quite often we will find ourselves needing to animate more than one parameter. A single `Double` just won't cut it. For these moments, we can use `AnimatablePair<First, Second>`. Here, `First` and `Second` are both types that conform to `VectorArithmetic`. For example `AnimatablePair<CGFloat, Double>`.

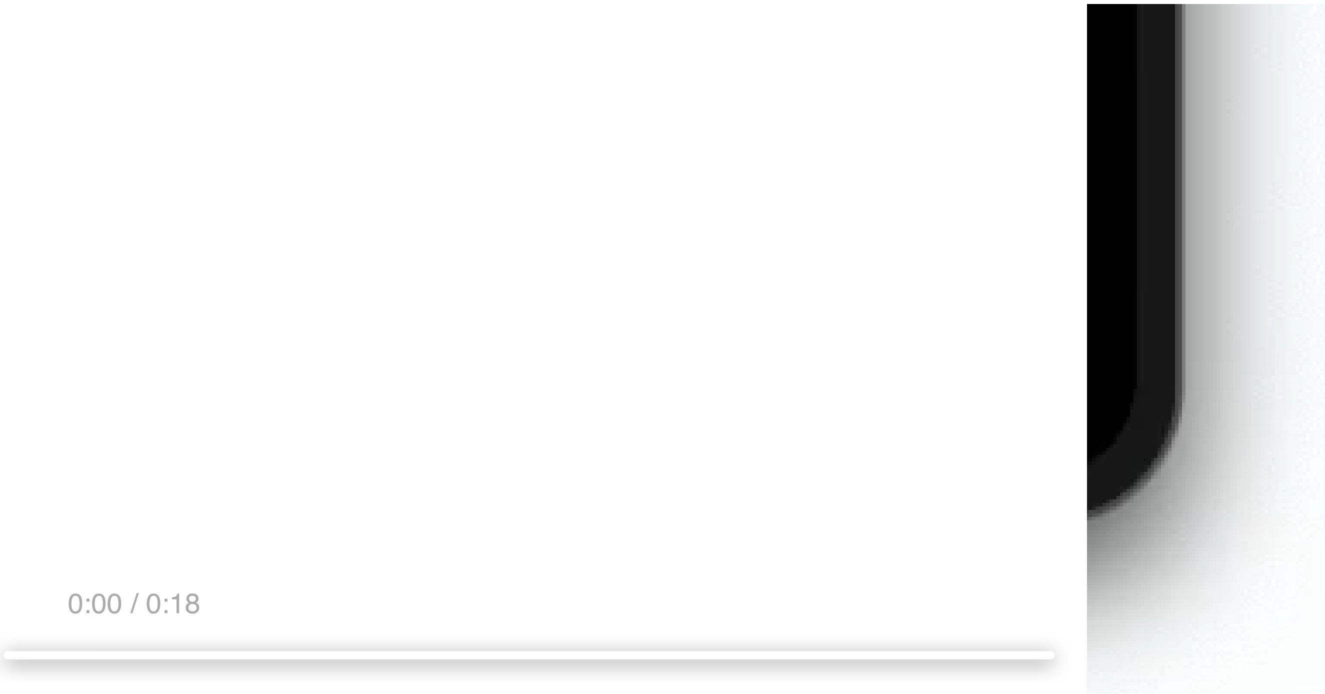


To demonstrate the use of `AnimatablePair`, we will modify our example. Now our polygon shape will have two parameters: `sides` and `scale`. Both will be represented with a `Double`.

```
struct PolygonShape: Shape {
    var sides: Double
    var scale: Double

    var animatableData: AnimatablePair<Double, Double> {
        get { AnimatablePair(sides, scale) }
        set {
            sides = newValue.first
            scale = newValue.second
        }
    }

    ...
}
```

The complete code is available as ***Example3***, in the gist file linked at the top the article. **Example4** in the same file, has an even more complex path. It is basically the same shape, but adds a line connecting every vertex with each other.





Going Beyond Two Animatable Parameters

If you browse the SwiftUI declaration file, you will see that the framework uses `AnimatablePair` quite extensively. For example: `CGSize`, `CGPoint`, `CGRect`. Although these types do not conform to `VectorArithmetic`, they can be animated, because they do conform to `Animatable`.

They all use `AnimatablePair` in one way or another:

```
extension CGPoint : Animatable {
    public typealias AnimatableData = AnimatablePair<CGFloat, CGFloat>
    public var animatableData: CGPoint.AnimatableData
}

extension CGSize : Animatable {
    public typealias AnimatableData = AnimatablePair<CGFloat, CGFloat>
    public var animatableData: CGSize.AnimatableData
}

extension CGRect : Animatable {
    public typealias AnimatableData = AnimatablePair<CGPoint.AnimatableData, CGSize.AnimatableData>
    public var animatableData: CGRect.AnimatableData
}
```

If you pay closer attention to CGRect, you will see that it is actually using:

```
AnimatablePair<AnimatablePair<CGFloat, CGFloat>, AnimatablePair<CGFloat, CGFloat>>
```

This means the r

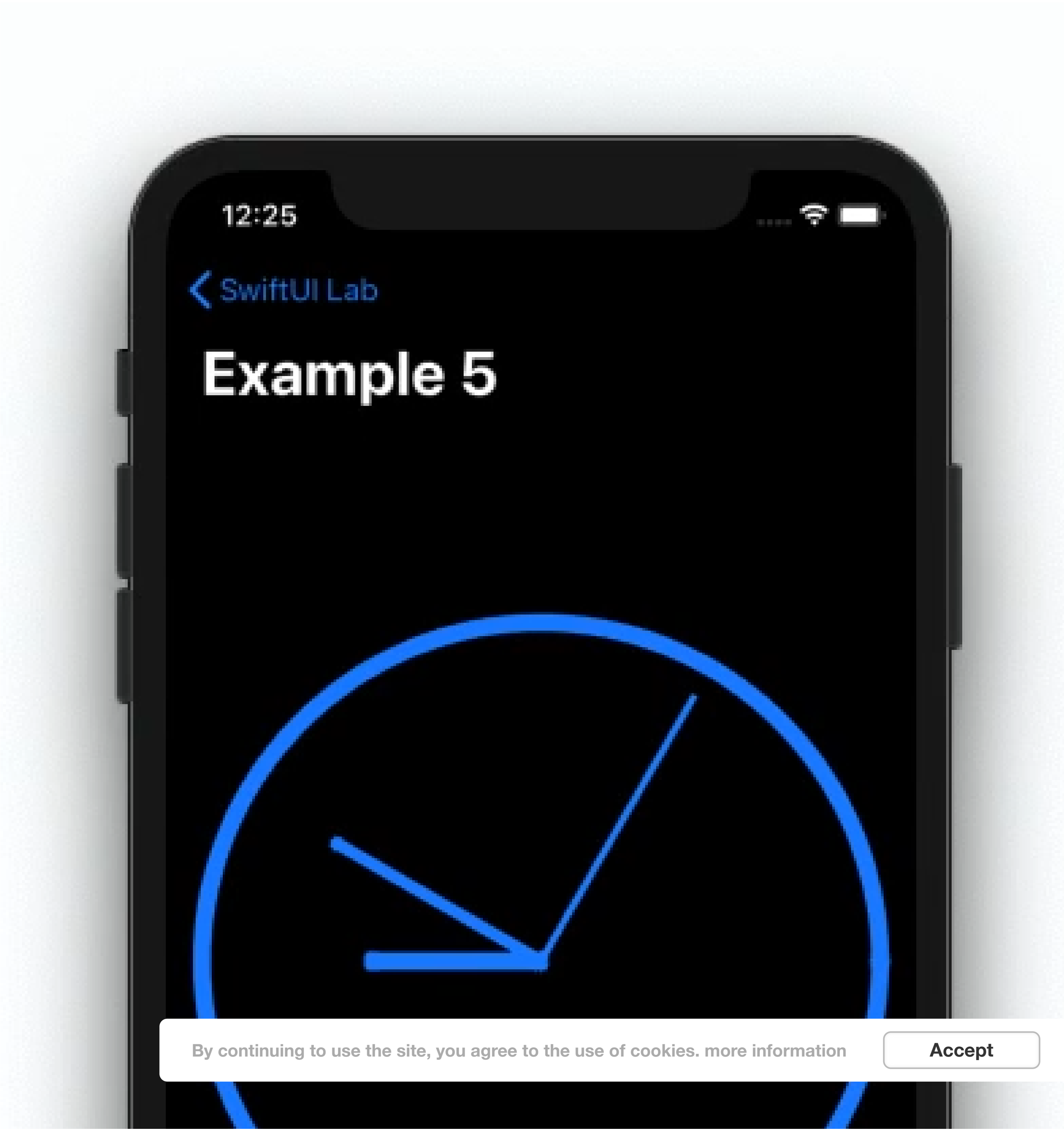
`second.first` and `second.second`.

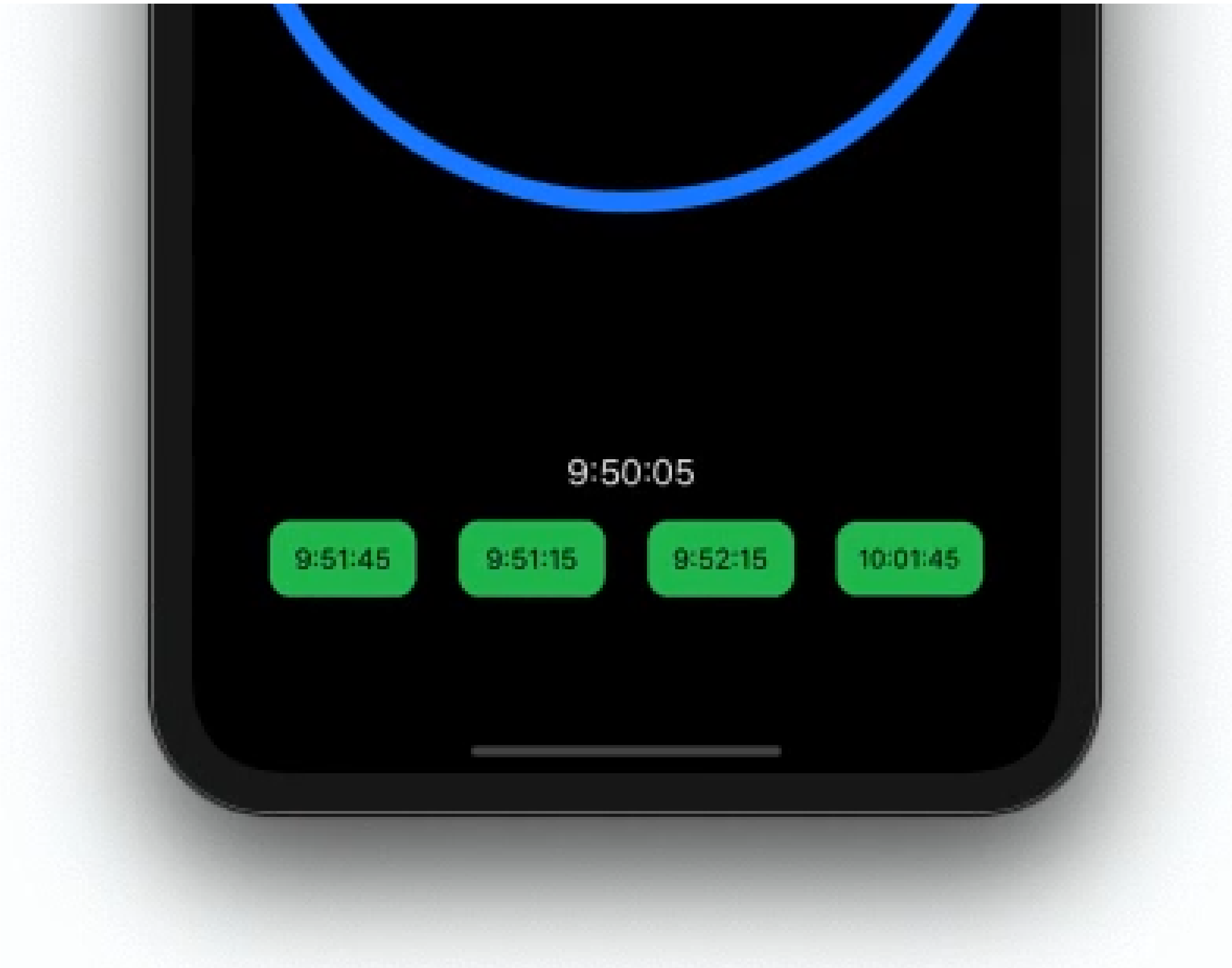
Making Your Own Type Animatable (with VectorArithmetic)

The following types conform to **Animatable**: `Angle`, `CGPoint`, `CGRect`, `CGSize`, `EdgeInsets`, `StrokeStyle` and `UnitPoint`. And the following types conform to **VectorArithmetic**: `AnimatablePair`, `CGFloat`, `Double`, `EmptyAnimatableData` and `Float`. You can use any of them to animate your shape.

The existing types offer enough flexibility to animate anything. However, if you find yourself with a complex type you want to animate, nothing prevents you from adding your own implementation of the VectorArithmetic conformance. In fact, we will do it in the next example.

To illustrate, we are going to create an analog Clock shape. It will move its needles according to a custom animatable parameter of type: `ClockTime`.





We are going to be using it like this:

```
ClockShape(clockTime: show ? ClockTime(9, 51, 15) : ClockTime(9, 55, 00))
    .stroke(Color.blue, lineWidth: 3)
    .animation(.easeInOut(duration: duration))
```

First, we begin by creating our custom type **ClockTime**. It contains three properties (hours, minutes and seconds), a couple of useful initializers, and some helper computed properties and methods:

```
struct ClockTime {
    var hours: Int      // Hour needle should jump by integer numbers
    var minutes: Int    // Minute needle should jump by integer numbers
    var seconds: Double // Second needle should move smoothly

    // Initializer with hour, minute and seconds
    init(_ h: Int, _ m: Int, _ s: Double) {
        self.hours = h
        self.
        self.
    }

    // Initializer with total of seconds
```

```
    // initializer with total of seconds
    init(_ seconds: Double) {
        let h = Int(seconds) / 3600
        let m = (Int(seconds) - (h * 3600)) / 60
        let s = seconds - Double((h * 3600) + (m * 60))

        self.hours = h
        self.minutes = m
        self.seconds = s
    }

    // compute number of seconds
    var asSeconds: Double {
        return Double(self.hours * 3600 + self.minutes * 60) + self.seconds
    }

    // show as string
    func asString() -> String {
        return String(format: "%2i", self.hours) + ":" + String(format: "%02i", self.minutes) + ":"
    }
}
```

Now, to conform to VectorArithmetic, we need to write the following methods and computed properties:

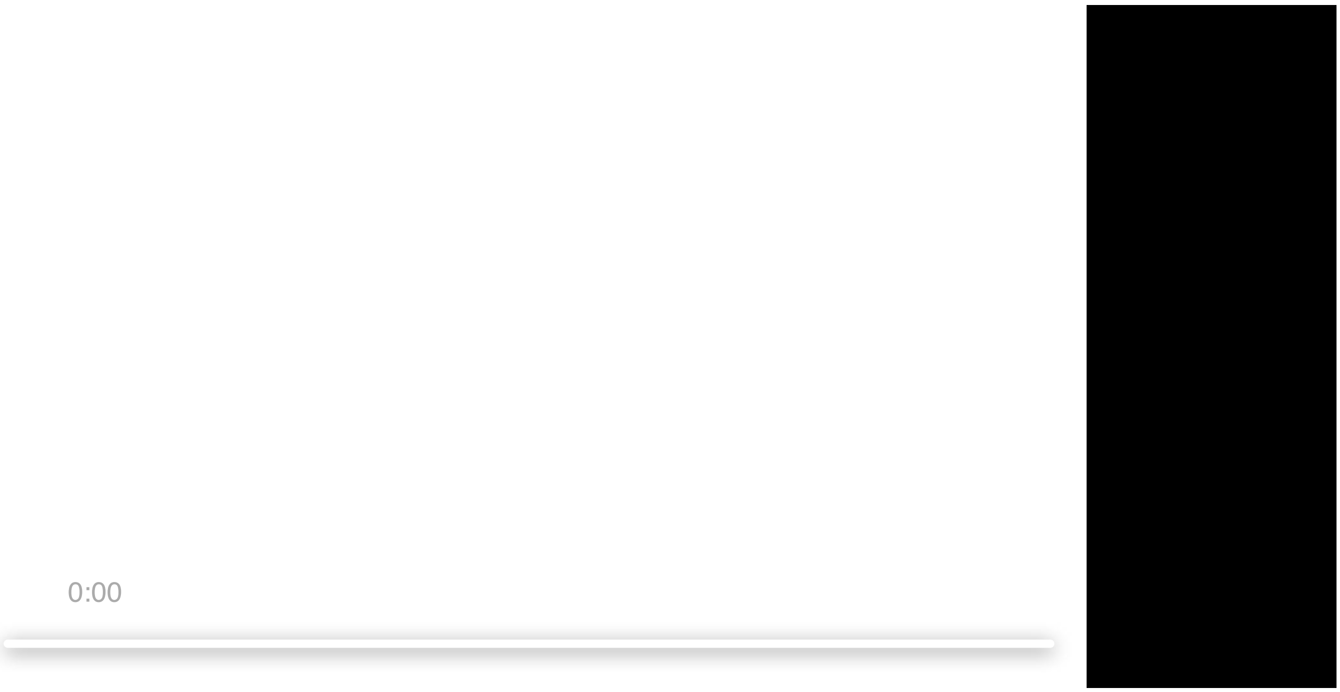
```
extension ClockTime: VectorArithmetic {
    static var zero: ClockTime {
        return ClockTime(0, 0, 0)
    }

    var magnitudeSquared: Double { return asSeconds * asSeconds }

    static func -= (lhs: inout ClockTime, rhs: ClockTime) {
        lhs = lhs - rhs
    }

    static func - (lhs: ClockTime, rhs: ClockTime) -> ClockTime {
        return ClockTime(lhs.asSeconds - rhs.asSeconds)
    }

    static func += (lhs: inout ClockTime, rhs: ClockTime) {
        lhs = lhs + rhs
    }

    static func + (lhs: ClockTime, rhs: ClockTime) -> ClockTime {
        return ClockTime(lhs.asSeconds + rhs.asSeconds)
    }

    mutating func scale(by rhs: Double) {
        var s = Double(self.asSeconds)
        s.scale(by: rhs)

        let ct = ClockTime(s)
        self.hours = ct.hours
        self.
        self.
```

```
    }
}
```

The only thing left to do, is writing the shape to position the needles appropriately. The full code of the Clock shape, is available as **Example5** in the gist file linked at the top of this article.

SwiftUI + Metal

If you find yourself coding complex animations, you may start to see your device suffering, while trying to keep up with all the drawing. If so, you could definitely benefit from enabling the use of Metal. Here's an example of how having Metal enabled, makes all the difference:



When running on the simulator, you may not perceive much difference. However, on the real device, you will. The video demonstration is from an iPad 6th generation (2016). Full code is in the gist file, under name **Example6**.

Fortunately, enabling Metal, is extremely easy. You just need to add the `.drawingGroup()` modifier:

```
FlowerView().drawingGroup()
```

According to WWDC 2019, Session 237 ([Building Custom Views with SwiftUI]): A drawing group is a special way of rendering but only for things like graphics. It will basically flatten the SwiftUI view into a single NSView/UIView and render it with metal. Jump the WWDC video to 37:27 for a little more detail.

If you want to try it out, but your shapes are not complex enough to make the device struggle, add some gradients and shadows and you will immediately see the difference.

What's N

In the second part of this article, we will learn how to use the GeometryEffect protocol. It will open the door to new ways of altering our views and animating them. As with Paths, SwiftUI has no built-in knowledge on how it can transition between two different transform matrices. GeometryEffect will be helpful in doing so.

At this moment, SwiftUI has no keyframe functionality. We will see how we can emulate one with a basic animation.

In the third part of the article we will introduce AnimatableModifier, a very powerful tool that will let us animate anything that can change in a View, even Text! For some examples of the animations included in this 3 part series, check the video below:

Advanced SwiftUI Animations

Make sure you don't miss the next part of the article when it becomes available. And please feel free to comment. You can also follow me on twitter, if you want to be notified when new articles come out. The link's below. Until then…

Animations, SwiftUI

‹ ScrollView – Pull to Refresh

› Advanced SwiftUI Animations – Part 2: GeometryEffect

18 thoughts on "Advanced SwiftUI Animations – Part 1: Paths"

Vlad

September 3, 2019 at 12:46 pm

Hi,

I tried to go through your article by incrementally creating the same project in Xcode. However when trying to use PolygonShape, the project crashes with some sort of EXC_BAD_INSTRUCTION error.

Any idea on how to solve this ?

Thanks.

Reply

javier

September 4, 2019 at 4:48 am

Are you using Xcode 11, Beta 5? There is a known bug that crashes when using Paths. The problem has been resolved in Beta 6.

Reply

Alexandre Lordelo

September 27, 2019 at 9:13 pm

Absolutely amazing tutorial Javier! Do you know it there is the equivalent of a "control point" and "handlers" in SwiftUI, where you can control a quadratic curve (like in sketch app for ex)?

Cheers!

Reply

Anonymous

October 3, 2019 at 2:09 pm

I have read many documents already and do not understand what is animatable?

Reply

lionel

November 10, 2019 at 8:50 am

great tutorial, informative, illustrative
one thing to note, the code of animationTime always return 1

Reply

javier

November 12, 2019 at 7:31 pm

Thanks! Updated now 😉

Reply

Matteo

December 17, 2019 at 12:39 am

Did you guys see that a new API about animations has recently been released? I hadn't spotted it until I updated xCode to version 11.3. The API I'm talking about is https://developer.apple.com/documentation/swiftui/equatableview/3267674-animation and let us use implicit animations on a View only when a specific value changes. It seems really powerful and it actually fixes some weird behaviours on implicit animations that used to happen (for instance when you tried to stop animations with `animation(nil)` modifier that sometimes it caused all the animations to stop on the view itself).

Reply

javier

December 18, 2019 at 5:49 am

Hi Matteo, that modifier was always there. At least since Xcode 11.0

Reply

AHMED M ALBAQAWI

January 6, 2020 at 8:27 pm

Hi Javier,

This is an awesome article and cant wait to finish the entire series.

I have a simple question, excuse if it is not a smart one! In example #1 let us say I choose #3 for 3 sides. I get the animations from 4 sides to 3. The loop [for i in 0..<(Int(sides) + extra) {…..}]gets executed. I placed some print() statements to monitor progress of all variables.

However, if I press #3 again nothing happens, it seems the loop [for i in 0..<(Int(sides) + extra) {…..}] is never run.

Am I missing something with Animatable/animatableData or is it something else doing the animation prevention?

Reply

javier

January 7, 2020 at 7:44 am

You are correct, the loop will not run. Since the `sides` state variable does not change its value (remains at 3), SwiftUI knows the view does not need recomputing. You may learn more about that in this other article I wrote: https://swiftui-lab.com/equatableview/

Reply

Gavitron

February 28, 2020 at 5:55 pm

I am a beginner and I love these tutorials!
For Example4, wondering why you used a recursive function with a loop instead of a double for loop?
Thanks!

Reply

javier

February 29, 2020 at 11:39 am

Hi Gavitron. I don't remember why I used the recursive function. It was probably the first solution that came to mind. I like recursive functions, because it makes the code easier to read (this is subjective, of course).

Nevertheless, that it is a very interesting topic and has been thoroughly investigated. Check the Wikipedia entry for "Primitive Recursive Function":
`https://en.wikipedia.org/wiki/Primitive_recursive_function`.

Reply

Theo

July 4, 2020 at 1:14 pm

Hi Javier,

Great tutorial! I noticed that without this line:

let extra: Int = Double(sides) != Double(Int(sides)) ? 1 : 0

the animation does not work correctly but I can't understand exactly why. Would you mind elaborating a bit?

Reply

javier

July 5, 2020 at 8:22 pm

I've written it a long time ago, but I see if I can remember. When drawing the polygon during an animation, the number of sides is not necessarily an integer number. The shape may need to draw a polygon of let's say, 3.2 sides. If that line weren't there, the loop would iterate 3 items, one for each complete side. That line forces the loop to have an extra iteration when the number of sides is not an integer, so we can calculate the extra and smaller side. That is, three cycles for the 3 full sides, and an extra cycle for the shorter side (0.2).

Reply

Louis Lac

July 21, 2020 at 5:36 pm

Great tutori

Just noticed that the `PolygonShape` struct can be simplified further:
– No need to have two properties `sides` and `sidesAsDouble`, only `sidesAsDouble` is required and `sides` can be a computed property, this saves some space.
– `sidesAsDouble` can be made a `CGFloat` directly, it simplifies a lot the code in `path()`.
– `let extra: Int = sidesAsDouble != Double(Int(sidesAsDouble)) ? 1 : 0` feels a bit awkward and is in fact not needed, just iterate 1 more point every time: `for i in 0…Int(sidesAsDouble)`. It makes the code cleaner and potentially faster.
– `let angle = (Double(i) * (360.0 / sidesAsDouble)) * Double.pi / 180` can be simplified: `let angle = 2 * CGFloat(i) * .pi / CGFloat(sides)` (with sides a `CGFloat`).

And more if performance is needed:
– The division computation in angle can be removed from the loop.
– `if-else` condition can be remove from the loop.

Reply

javier

July 24, 2020 at 2:00 pm

Thanks for all the suggestions. I will definitely incorporate some of them.

Reply

Ankush Anand

August 23, 2020 at 10:10 am

The best article with awesome examples to understand the depth of working with custom animation in SwiftUI.

Thank you, Javier. Yours content is awesome as you.
Cheers mate

Reply

Ismael

October 2, 2021 at 3:04 pm

great Article , thanks a lot for the effort.

Reply

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javier@swiftui-lab.com

@SwiftUILab