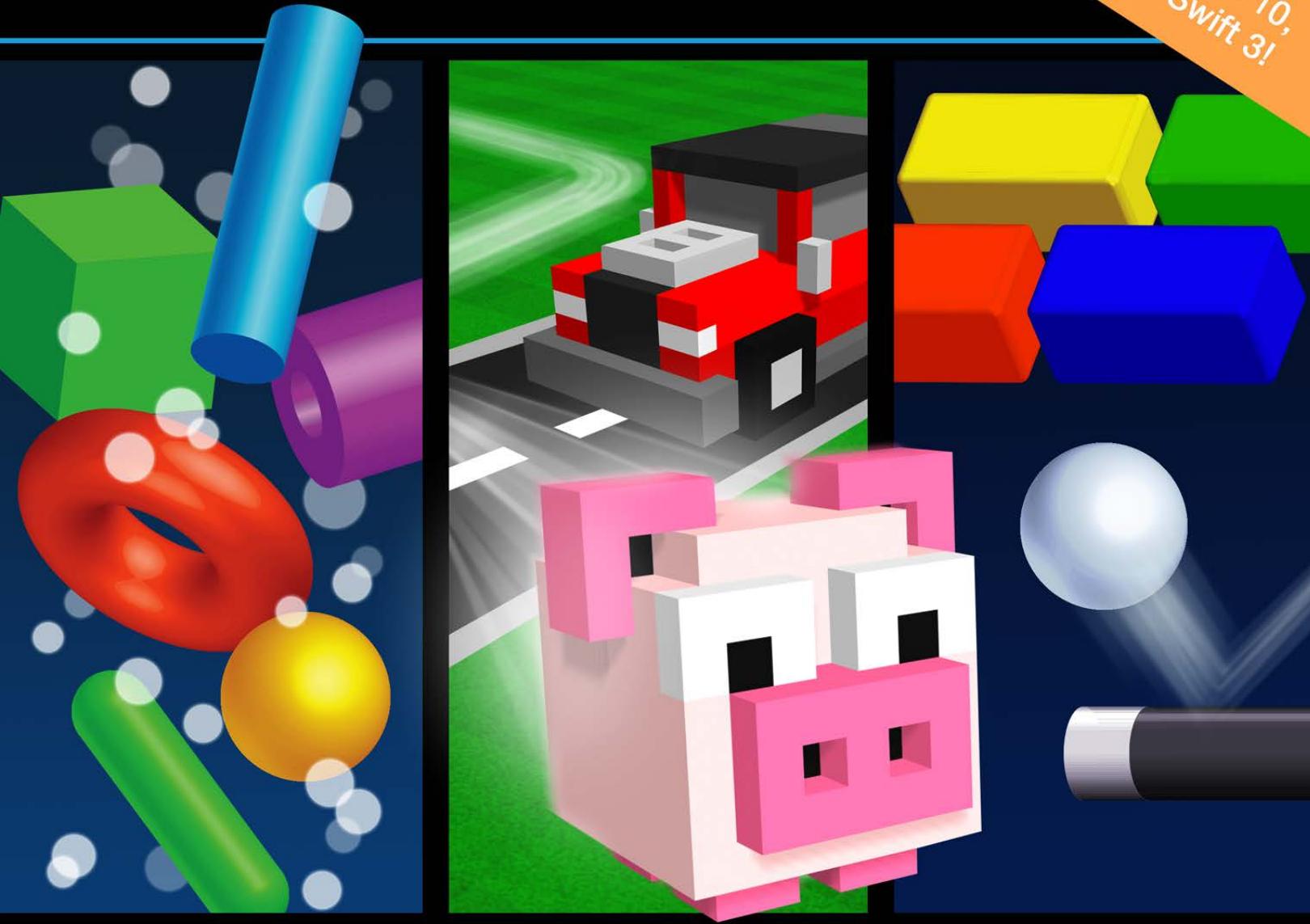


Beginning 3D iOS Game
Development with Swift 3

Up to date for iOS 10,
Xcode 8, and Swift 3!



3D Apple Games

by Tutorials

By Chris Language

3D Apple Games by Tutorials

Chris Language

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Dedications

"To my wife Corné and my daughter Marizé. Thank you for your patience, support, belief, and most of all, your love. Everything I do, I do for you."

— *Chris Language*

About the author



Chris Language is a seasoned coder with 20+ years of experience. He has fond memories of his childhood and his Commodore 64; more recently he started adding more good memories of life with all his iOS devices. By day, he fights for survival in the corporate jungle of Johannesburg, South Africa. By night he fights demons, dragons and angry little potty-mouth kids online. For relaxation he codes. You can find him on Twitter [@ChrisLanguage](#). Forever Coder, Artist, Musician, Gamer and Dreamer.

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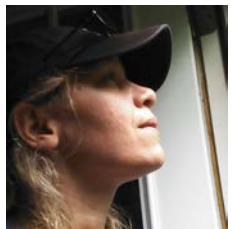
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Introduction

You'd be forgiven for thinking that making 3D games is far more complicated than creating a classic 2D game. 3D games have a reputation for being notoriously difficult to program, usually involving a lot of complicated math.

However, that is no longer the case, thanks to the advent of SceneKit. The simplicity of SceneKit lets beginners create simple and stylish games in a short amount of time. Yet it's also powerful enough to satisfy the needs of advanced developers who want to create the next FPS killer.

Hopefully this sounds awesome to you, but you might have a few questions about the technology used in this book. Here's the reasoning behind our choice of SceneKit:

- **Why SceneKit?** Apple's built-in framework for making 3D games is easy to learn, especially if you already have some SpriteKit and Swift experience.
- **Why Swift?** Swift is an easy language to get started with, especially if you are a beginner to Apple development. In addition, we believe Swift is the way of the future for Apple development, so take this as an opportunity to develop your Swift skills early!
- **Why 3D?** As awesome as 2D games may be, 3D games have a greater appeal in the look and feel department. Creating modern artwork such as popular voxel-style graphics is easier than ever. With SceneKit, even the programming is far less complicated than ever before, and you don't need an advanced math or physics degree! :] All of this puts 3D firmly within your grasp.

So rest easy — with 3D games and SceneKit, you're making great choices!

A history of SceneKit

Making 3D games with SceneKit on iOS, watchOS, tvOS and macOS is easy — but it wasn't always that way. Historically, your only option was to use OpenGL ES, which (along with Metal) is the lowest-level 3D graphics API available.

Unfortunately, OpenGL ES is quite the untamable monster, which often left puny little beginner game developers running with their tails between their legs, seeking for alternative options. Unity offered a great alternative, but did so at the cost of having to learn an entirely new programming paradigm.

To solve this, Apple introduced SceneKit to OS X developers with the release of OS X Mountain Lion back in 2012. Two years later, SceneKit made a surprise debut in iOS with the release of iOS 8. Not long after that, support for watchOS and tvOS followed suit.

At the time, iOS developers were already familiar with SpriteKit, Apple's graphics framework for 2D games. What makes SceneKit so attractive is the seamless integration between SpriteKit and SceneKit. Now, SpriteKit can easily incorporate 3D content into 2D scenes, and SceneKit can easily incorporate the 2D power of SpriteKit into 3D scenes, giving the developers the best of both worlds.

SceneKit sits on top of OpenGL ES; iOS 9 added support for Metal. This gives you the freedom to choose between Metal, to give your SceneKit game that "closer to metal" performance, or OpenGL ES if you still want to use the OpenGL ES API.

Just like SpriteKit, the SceneKit API is well-designed and easy to use — especially for beginners. Best of all, you can use it knowing it's fully supported by Apple and heavily optimized for 3D gaming on iOS, watchOS, tvOS and macOS.

From here on out, if you want to make a 3D game on Apple's large selection of amazing platforms, we definitely recommend you use SceneKit rather than other game frameworks – with one exception.

If you're looking to make a cross-platform game to run on Android or Windows as well as on iOS or macOS, be aware that SceneKit only serves Apple platforms. Porting your game to non-Apple platforms would be easier in a tool that's designed for cross-platform games, such as Unity.

If you want to make a 3D game for Apple platforms only, then SceneKit is definitely the way to go!

What you need

To follow along with the tutorials in this book, you'll need the following:

- **A Mac running OS X El Capitan or later:** This is so you can install the latest version of the required development tool: Xcode.
- **Xcode 8 or later:** Xcode is the main development tool for iOS, watchOS, tvOS and macOS; you'll need Xcode 8 or later to follow along with this book.
- **An iPhone, Apple Watch or an Apple TV:** For most of the chapters in the book, you can run your code on a simulator that comes with Xcode. However, there are a few chapters later in the book that require a device for testing. Also note that SceneKit performs much better on physical devices than it does in the simulator, so your frame rates will appear lower than expected when running your game in the simulator.

If you don't have the latest version of Xcode installed, be sure to do that before continuing with the book.

Who this book is for

This book is for beginning to advanced Apple developers. Wherever you fall on that spectrum, you will learn a lot from this book!

This book does require some basic knowledge of Swift. If you're not familiar with Swift, you can still follow along with the book as all instructions are in a step-by-step format. However, there will likely be parts that are confusing due to gaps in your knowledge. Before starting this book, you might want to go through our Swift Apprentice series, which covers the basics of Swift development:

- www.raywenderlich.com/store

How to use this book

There are two ways to use this book, depending on whether you are a complete newcomer to Apple game development, or an advanced developer with knowledge of other 3D game frameworks.

If you are a complete beginner

If you're a complete beginner to Apple game development, the best way to read this book is from cover to cover. We have arranged the chapters to introduce the material in the most logical manner to build up your skills one layer at a time.

If you are an advanced developer

If you're an advanced developer with knowledge of other 3D game frameworks, you will have an easier time adapting to SceneKit, as the core concepts and syntax will look very familiar.

Our suggestion is to skim through the early chapters and focus more on the later, more advanced chapters, or areas where you have a particular interest.

Don't worry — you can jump right into any chapter in the book, because we'll always have a starter project waiting for you!

What's ahead: an overview

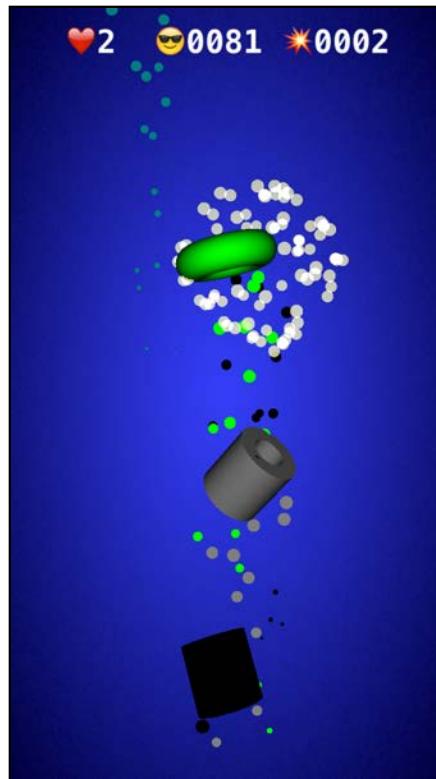
3D Apple Games by Tutorials is split into six sections and moves from beginning to advanced topics. Throughout the process, you will create four complete mini-games from scratch!

Take a look at what's ahead.

Section I: Hello, Scene Kit!

This section covers the basics of making 3D games with Scene Kit. You'll look at the most important techniques used in almost every 3D Scene Kit game created, and by the end of this section you'll know enough to make your very own little 3D game: Geometry Fighter.

This is a *Fruit Ninja* style game, with colorful geometric shapes thrown up into the air for your pure destructive indulgence. Seek out your inner Darth Vader and use the force to destroy the colorful shapes with a single touch of death! :]



1. **Chapter 1, Scenes:** Start off by creating your very first SceneKit game project, and get to know the basics.
2. **Chapter 2, Nodes:** Learn how to use nodes, geometric shapes and cameras to construct a basic 3D scene from the ground up.
3. **Chapter 3, Physics:** Unleash the power of the built-in physics engine, and learn how to add basic physics to the elements in your game.
4. **Chapter 4, Render Loop:** Learn all about the render loop within SceneKit, and how you can leverage it to update the elements in your game.
5. **Chapter 5, Particle Systems:** Create massive explosions for your game, by learning how to create and use the 3D particle system.

Section II: The Scene Kit Editor

Xcode includes a variety of standard built-in tools, and in this section, you'll take an in-depth look at them. These tools will make building your 3D games with Scene Kit so much easier, faster and even more fun.

Throughout this section you'll be making a game named Breaker, which is based on *Breakout*, but it adds a nice new 3D look and feel. Keep your paddle and ball close by, so you can go bust up some bricks! :]



6. **Chapter 6, SceneKit Editor:** Get a hands-on introduction on how to use Xcode's awesome built-in SceneKit Editor.
7. **Chapter 7, Cameras:** Learn about the different types of cameras SceneKit has to offer.
8. **Chapter 8, Lights:** Learn all about the different types of lights, and how to properly set them up for your game.
9. **Chapter 9, Geometric Shapes:** Get your hands dirty and construct the entire game scene with just using the built-in SceneKit geometric shapes.
10. **Chapter 10, Basic Collision Detection:** Add physics to your game and learn how to handle basic collision detection.

Section III: Intermediate SceneKit

In this section you will create a stunning make-believe world, where exceptional balancing skills are needed to guide a shiny wooden relic through a maze high up in the sky. The game is named Marble Maze, and is somewhat based on the *Labyrinth* styled games — with a twist.



11. **Chapter 11, Materials:** Learn about the different lighting models and the various material types supported by SceneKit.
12. **Chapter 12, Reference Nodes:** Learn how to start using reference nodes in your game.
13. **Chapter 13, Shadows:** Learn how to use and configure the darker element of light, known as shadows.
14. **Chapter 14, Intermediate Collision Detection:** Learn all about bit masks and how to make use of them for more intermediate collision detection scenarios.
15. **Chapter 15, Motion Control:** Add motion control to your game, and learn how to use the motion data to move the elements in your game.

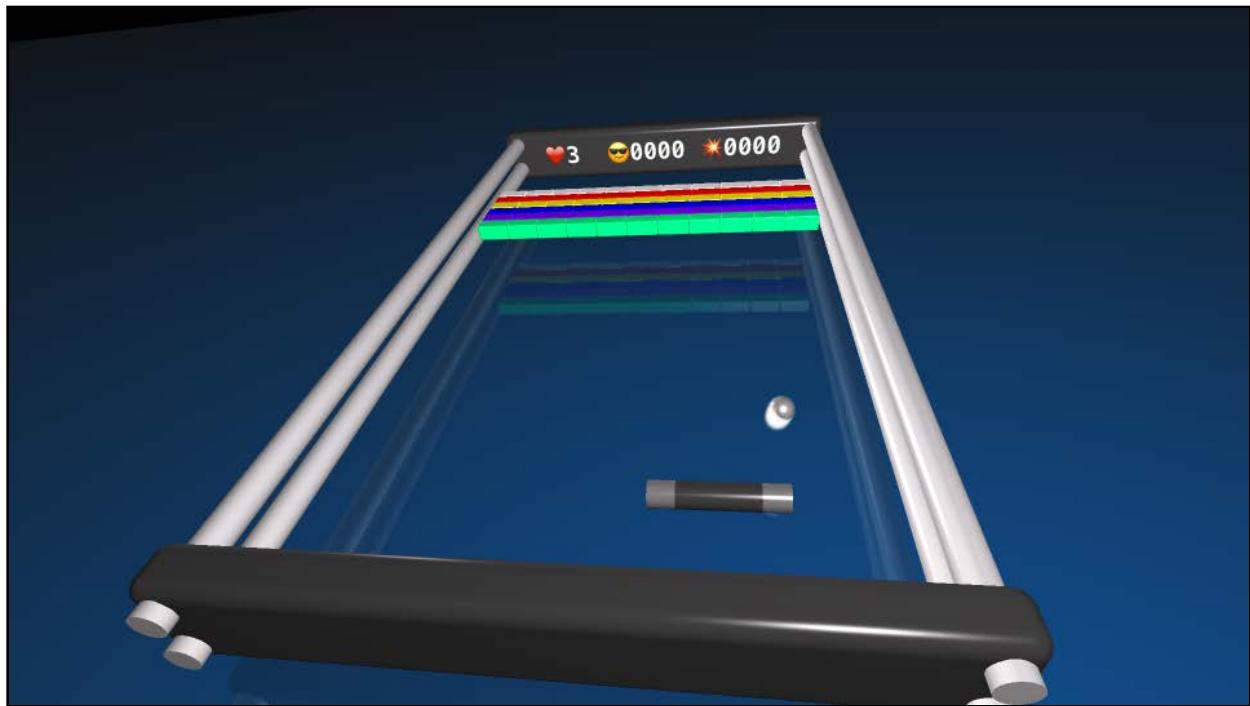
Section IV: Cross Platform Games

In this section, you'll learn a few cool tricks on how to make your games run on other platforms like *macOS*, *tvOS* and even *watchOS*.

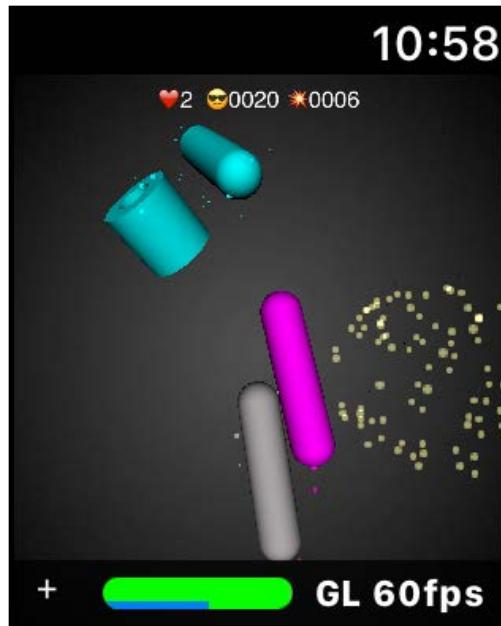
You'll start by creating a *macOS* version of *Geometry Fighter*.



Then, you'll create a *tvOS* version of *Breaker*.



Finally, you'll create a *watchOS* version of *Geometry Fighter*.



16. Chapter 16, macOS Games: Learn how to make games for macOS.

17. Chapter 17, tvOS Games: Learn how to make games for tvOS.

18. Chapter 18, watchOS Games: Learn how to make games for watchOS.

Section V: Advanced SceneKit

"The SceneKit Force is quite strong within you, young apprentice." (Read in a deep, heavy, asthmatic breathing voice. :])

You'll learn more advanced techniques and apply all the skills you've learned so far to create an awesome little voxel-style game. By the end of this section, you'll know enough to take on the big *Hipster Whales* out there with your very own game: Mr. Pig.



This is a *Crossy Road* style game with stunning voxel graphics, a catchy tune and some cool sound effects.

Mr. Pig is out-and-about scouting for lost coins in a nearby park while waiting for his late afternoon tea to heat up on the stove. Mr. Pig better watch his step, or he'll end up as pulled pork in the road. :] Our hero can carry quite a few coins with him, but to score, he has to deposit them at his little house.

No need to get your tail in a twist or ham it up — we'll walk you through every step of building the game!

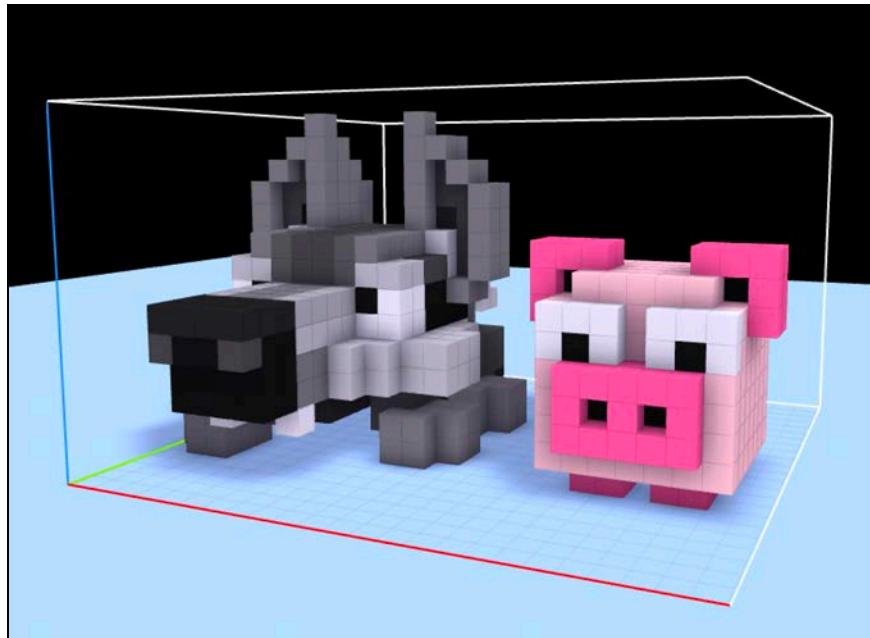
19. **Chapter 19, Transitions:** Create multiple scenes and learn how to transition from one to the other.
20. **Chapter 20, Advanced Reference Nodes:** Start building more complex scenes by leveraging the power of reference nodes to make scene-building child's play.
21. **Chapter 21, Actions:** Learn how to add basic animation to the elements in your game by using Xcode's built-in action editor.
22. **Chapter 22, Advanced Collision Detection:** Learn how to use more advanced collision techniques to solve certain scenarios.
23. **Chapter 23, Audio:** Harness SceneKit's built-in sound capabilities to play music, sound effects and ambient sounds.

Section VI: Bonus Chapter

Surprise! An entire section with bonus content.

In this section, you'll learn how to create your very own 3D art for your SceneKit games. In the process you'll learn how to create Mr. Pig from scratch. You'll also learn how to import your graphics into SceneKit.

Oh yeah, and there's a Mr. Wolf too! :]



24. Chapter 24, 3D Art for Programmers: Learn how to create your own 3D art for your games.

Book source code and forums

This book comes with complete source code for each of the chapters — it's shipped with the PDF. Some of the chapters have starter projects or other required resources that included as well; you'll definitely want to have these on hand as you go through the book.

We've set up an official forum for the book at raywenderlich.com/forums. This is a great place to ask any questions you have about the book or about making games with SceneKit, or to submit any errata you may find.

Book updates

Since you've purchased the PDF version of this book, you have free access to any updates we may make to the book!

The best way to get update notifications is to sign up for our weekly newsletter. This includes a list of the tutorials that came out on raywenderlich.com in the past week, any important news like book updates or new books, and our favorite Apple development links. You can sign up here:

- www.raywenderlich.com/newsletter

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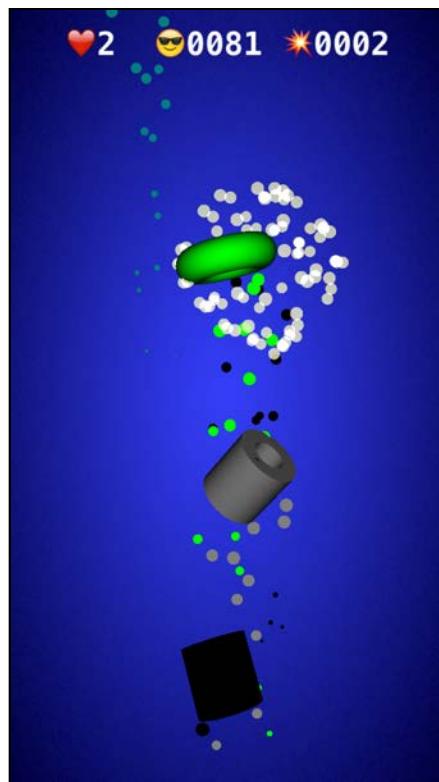
We would like to thank many people for their assistance in making this book possible:

- **Our families:** For bearing with us during this hectic time as we worked all hours of the night to get this book ready for publication!
- **Everyone at Apple:** For developing an amazing 3D game framework and other helpful APIs for games, for constantly inspiring us to improve our apps and skills, and for making it possible for many developers to have their dream jobs!
- And most importantly, **the readers of raywenderlich.com and you!** Thank you so much for reading our site and purchasing this book. Your continued readership and support is what makes this all possible!

Section I: Hello, SceneKit!

This section covers the basics of making 3D games with SceneKit. You'll look at the most important techniques used in almost every 3D SceneKit game created, and by the end of this section you'll know enough to make your very own little 3D game: Geometry Fighter.

This is a *Fruit Ninja* style game, with colorful geometric shapes thrown up into the air for your pure destructive indulgence. Seek out your inner Darth Vader and use the force to destroy the colorful shapes with a single touch of death! :]



[Chapter 1: Scenes](#)

[Chapter 2: Nodes](#)

[Chapter 3: Physics](#)

[Chapter 4: Render Loop](#)

[Chapter 5: Particle Systems](#)

Chapter 1: Scenes

Chris Language

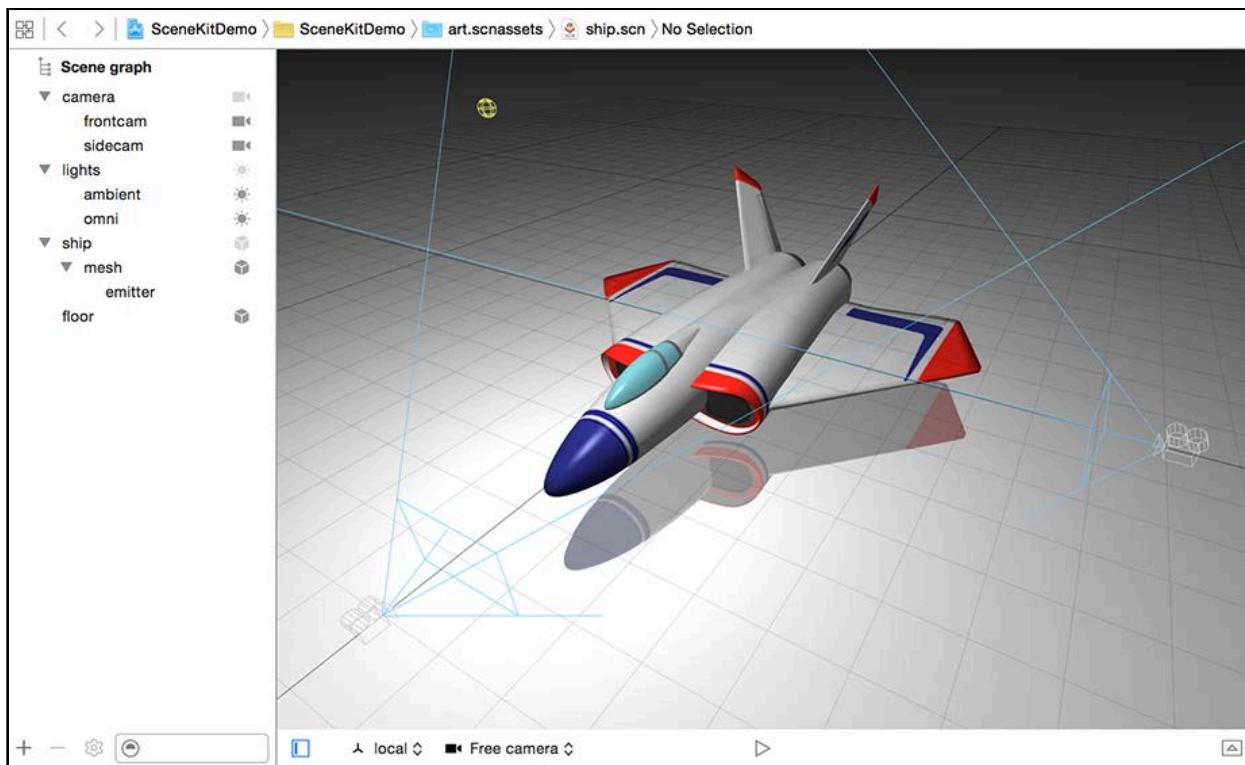
Getting started

In order to better understand the concepts behind SceneKit, you can draw some mental parallels between a SceneKit scene and a typical Hollywood movie scene.

A movie scene has basic components such as lights, cameras and props used to build the sets. It also has actors and actions the actors will perform when the director shouts, "Lights! Camera! Action!"

When you build a SceneKit scene from scratch, you'll add the same types of components as you build your project. SceneKit organizes these components into a node-based hierarchy known as the **scene graph**. A scene starts with a **root node** that defines the coordinate system; you add **content nodes** underneath the root node to form a tree structure. These content nodes are your basic building blocks for the scene and can include elements such as lights, cameras, geometry and particle emitters.

Consider the image below which shows a typical scene in SceneKit:



Note the node-based hierarchical structure on the left; it serves as a good example of the tree-like scene graph you'd construct within SceneKit. This particular screenshot is of Xcode's built-in SceneKit editor; hopefully this whets your appetite for things to come! :]

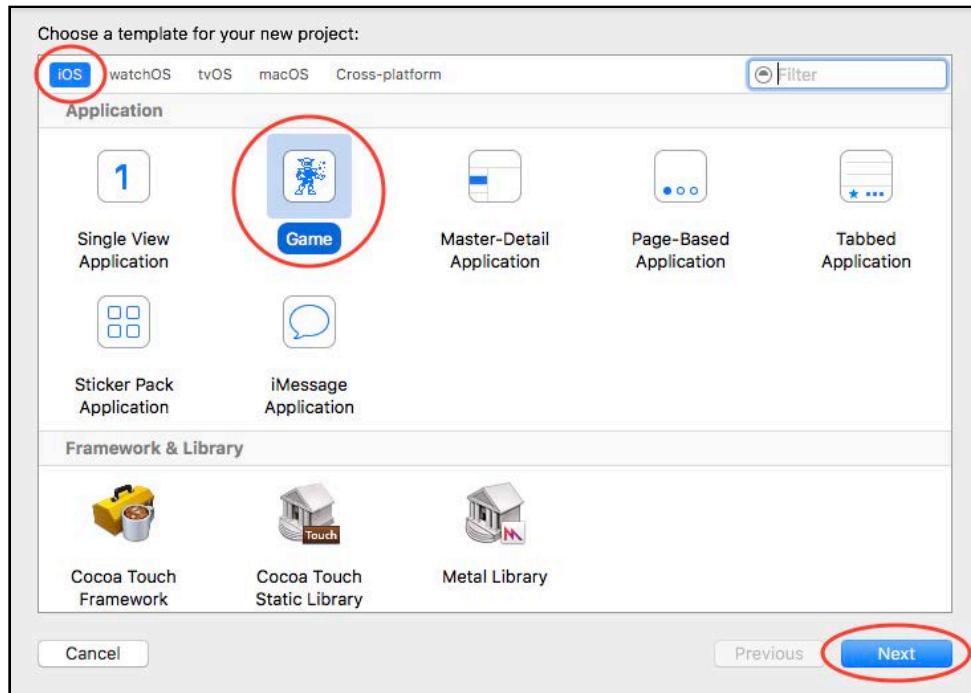
The game project

Now that you've covered a few basic concepts of SceneKit, it's time to dive right in and create your first SceneKit project. The sections below takes you through the process of creating a project using Xcode's built-in project template.

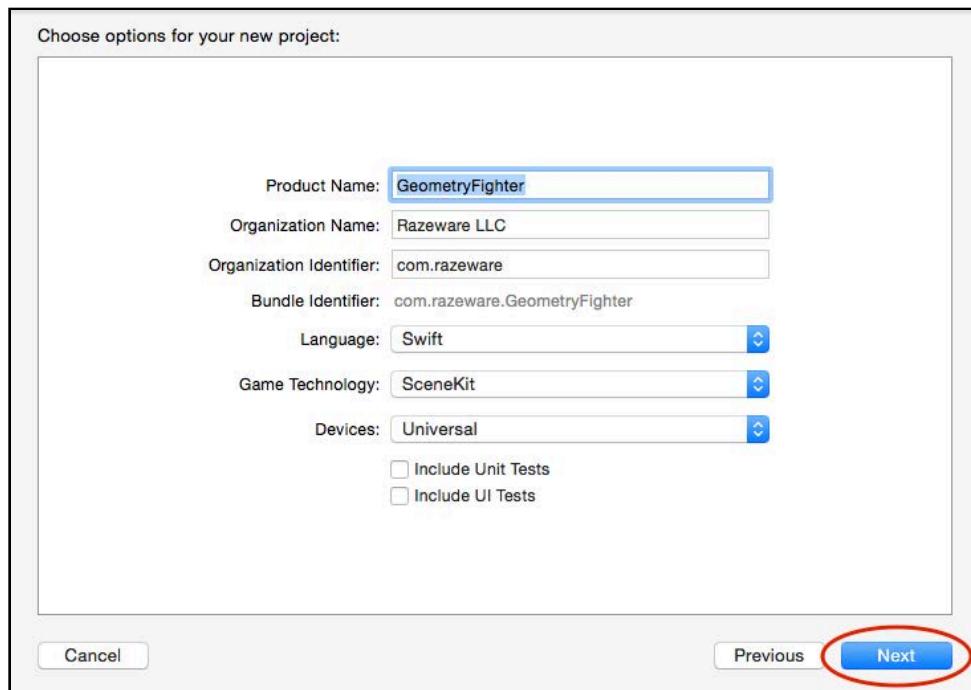
Creating a SceneKit game project

Open Xcode and select **File > New > Project** from the main menu. If you want to become an Xcode ninja, use the shortcut command: ⌘N.

Select the **iOS/Application/Game** template and click **Next** to continue:



Now you need to provide some basic details about your project. Enter **GeometryFighter** for the Product Name, select **Swift** for Language, **SceneKit** for Game Technology, **Universal** for Devices, uncheck the unit tests and click **Next**:

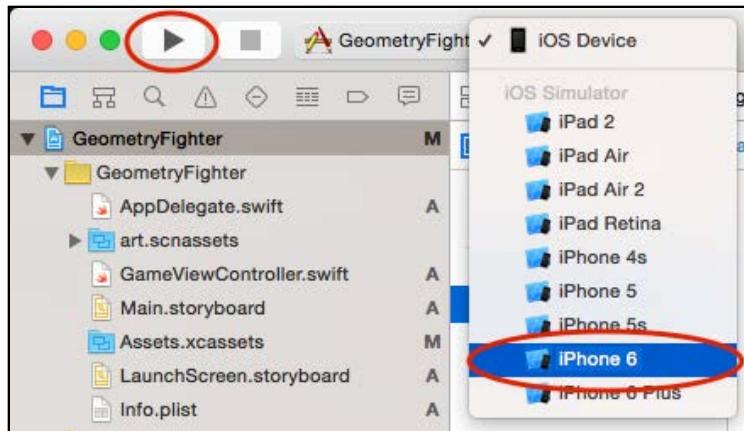


The final step is to choose a location to save your project. Pick a directory and select **Create**; Xcode will work its magic and generate your project.

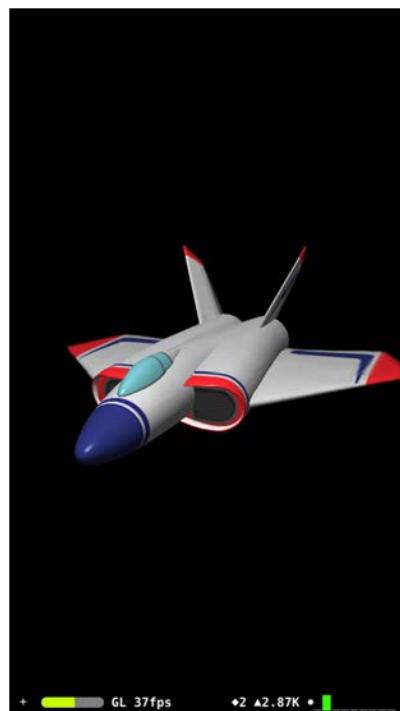
Building the SceneKit game project

Now that you've generated your SceneKit game project from the template, it's time to see it in action! :]

First, choose the **iPhone 6** simulator from the toolbar, then press the **Play** button at the top to build and run your project. Xcode ninjas can simply press **⌘R**:



You'll see the simulator launch, and your first 3D SceneKit game will appear. You can rotate the view of your 3D spaceship in the game by simply dragging around the screen in different directions to change the camera angle:



Cool, right? It's okay if you want to take a moment and do a little happy dance in your seat. When you're done, continue on with the rest of the chapter.

Challenge

It's time for your first mini-challenge! Before you move on, browse through the game template project. Pay close attention to the following key files and folders in the project navigator:

- **art.scnassets**
- **ship.scn**
- **GameViewController.swift**
- **Assets.xcassets**
- **LaunchScreen.storyboard**

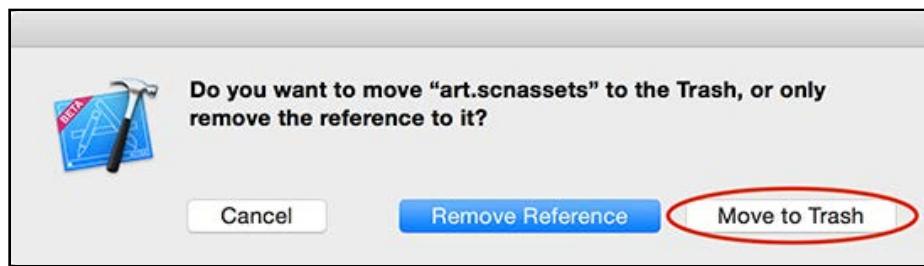
You may not understand how everything works yet, but try to figure out what you think each file might do. Because you'll be cleaning up the project in the next section, take a look at the files and folders while they're still around. :]

Cleaning up the game project

There are a few components you need to remove in order to start with a clean SceneKit game project. Don't worry; you'll re-create all of the content from scratch so you can get a better idea of how it works and from where it came.

Removing unwanted folders

The first thing to remove is the **art.scnassets** folder. Right-click the folder, select **Delete** and then click **Move to Trash**:



Note: For now, don't worry too much about the purpose of the **art.scnassets** folder. Just know that the Xcode SceneKit game template generated **art.scnassets** for you automatically.

Cleaning up main project files

The **GameViewController.swift** file is a key component of your game; it's where all of your game logic and code will live. Before you start coding, it's a good idea to purge all of the code the Xcode SceneKit game template created for you.

Replace the contents of **GameViewController.swift** with the following:

```
import UIKit
import SceneKit

class GameViewController: UIViewController {

    override func viewDidLoad() {
        super.viewDidLoad()
    }

    override var shouldAutorotate: Bool {
        return true
    }

    override var prefersStatusBarHidden: Bool {
        return true
    }
}
```

The boilerplate code generated the spaceship; you've replaced that code with an empty slate. `shouldAutorotate()` handles device rotation and `prefersStatusBarHidden()` hides the status bar.

Setting up SceneKit

Earlier, you learned how SceneKit uses the scene graph to display content on the screen. The `SCNScene` class represents a scene; you display the scene onscreen inside an instance of `SCNView`. Your next task is to set up a scene and its corresponding view in your project.

Setting up the project view

Add the following property to **GameViewController.swift**, just above `viewDidLoad()`:

```
var scnView: SCNView!
```

Here, you declare a property for the `SCNView` that renders the content of the `SCNScene` on the display.

Next, add the following function just below `prefersStatusBarHidden()`:

```
func setupView() {
```

```
    scnView = self.view as! SCNView  
}
```

Here, you cast `self.view` to a `SCNView` and store it in the `scnView` property so you don't have to re-cast it every time you need to reference the view. Note the view is already configured as an `SCNView` in **Main.storyboard**.

Note: `SCNView` is a subclass of `NSView` in macOS, and a subclass of `UIView` in iOS. So whether you're working with macOS or iOS, the same `SCNView` provides a view specifically for SceneKit content.

Setting up the project scene

It's time to set up your scene. Add the following property to **GameViewController.swift**, just below the `scnView` property:

```
var scnScene: SCNScene!
```

Here, you declare a property for the `SCNScene` in your game. You'll add components like lights, camera, geometry and particle emitters as children of this scene.

Now, add the following method below `setupView()`:

```
func setupScene() {  
    scnScene = SCNScene()  
    scnView.scene = scnScene  
}
```

This code creates a new blank instance of `SCNScene` and stores it in `scnScene`; it then sets this blank scene as the one for `scnView` to use.

Adding finishing touches

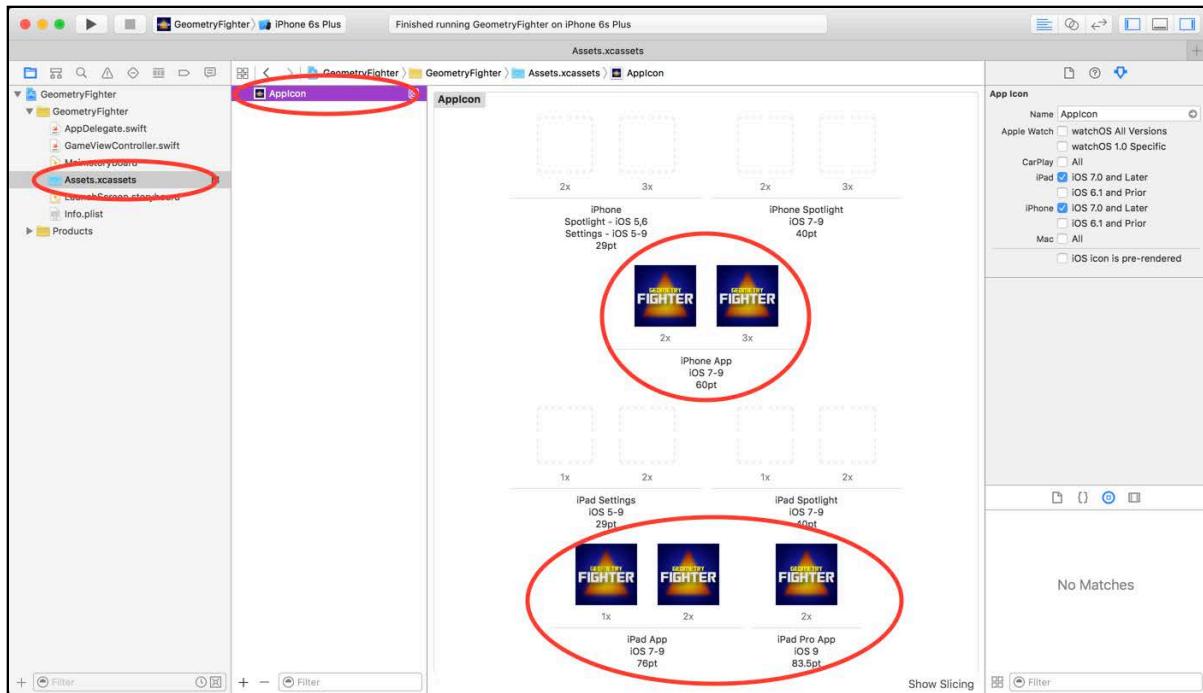
Now that you've created methods to set up instances of `SCNView` and `SCNScene`, you'll need to call them from somewhere during the initialization step. A good place for that is just after the view finishes loading.

Add the following lines to `viewDidLoad()`, just after the call to `super`:

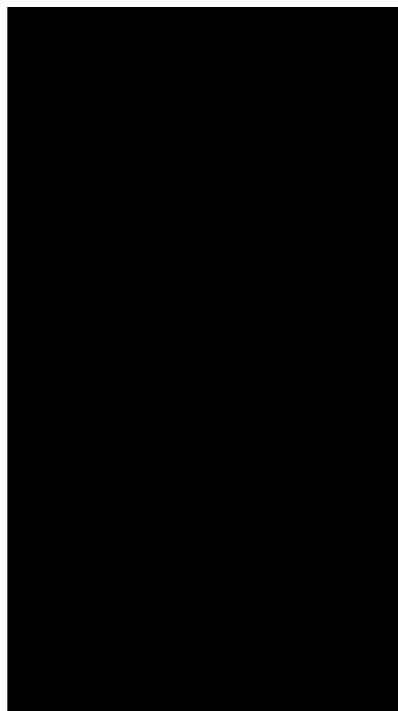
```
setupView()  
setupScene()
```

Now it's time to add an app icon to your game. Take a look in the **Resources** folder; you'll find app icons of various sizes which you can use for this project.

To set an image as the icon for your game, open the **Assets.xcassets** folder, select the **AppIcon** entry and drag each file from the **Resources** folder to the appropriate spot. Your AppIcon panel should look like the following when you're done:



Build and run your project. Behold — the blank screen of opportunity! :]



Where to go from here?

Granted, this might not seem very impressive at first, but you've come a long way already:

- You created a basic SceneKit game project that uses the built-in SceneKit game template.
- You learned how to clean up the project by removing unnecessary folders such as **art.scnassets**.
- Finally, you learned how to initialize an SCNView with a blank SCNScene.

Now that you have a blank slate to work with, keep reading to start making your first SceneKit game!

Chapter 2: Nodes

Chris Language

Getting started

In the previous chapter, you learned that SceneKit organizes the components of your game into a hierarchy known as the **scene graph**.

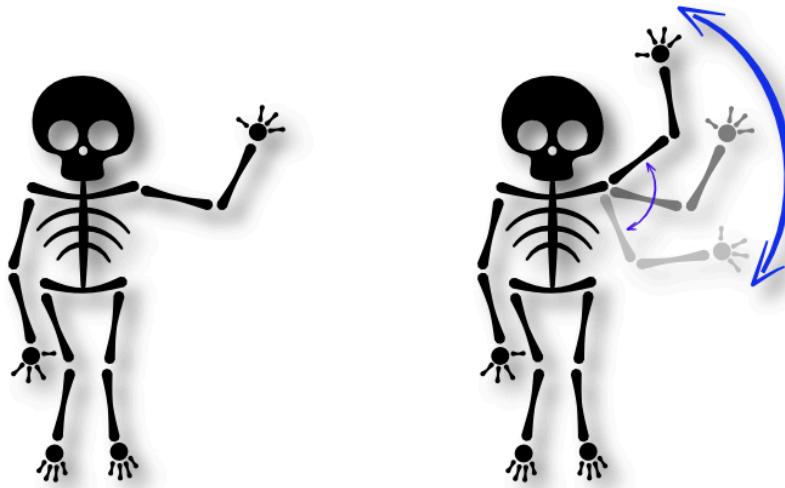
Each element of your game — such as lights, cameras, geometry and particle emitters — are called **nodes**; and nodes are stored in this tree-like structure.

To illustrate how this works, think back to a childhood nursery rhyme you might have heard...

🎵 *The hip bone's connected to the back bone* 🎵 *The back bone's connected to the shoulder bone...* 🎵

You're right! It's the classic song *Dem Dry Bones*. Bonus points if you know a classic video game that makes particularly good use of this concept. ;]

With those lyrics in mind, take a look at the following *anatomically-correct* structure of a rare four-fingered skeleton:



To help illustrate how you can construct a node-based hierarchy from this skeleton, think of each bone in the skeleton as a **node**.

As the song points out, the shoulder bone's connected to the back bone. So consider the back bone as the **parent** node of the shoulder bone, and the shoulder bone as the **child** node of the back bone.

To add the shoulder bone to the scene, you add it as a child of the back bone. You can continue to construct the whole arm in this way, adding child bones to parent bones, right up to the little pinky.

To position a bone, you position it relative to its parent. For example, to wave the skeleton's left arm, you simply rotate the shoulder node back and forth as indicated by the little blue arrow. All child nodes of the shoulder node will rotate along with their parent.

Congratulations! You just passed skeleton anatomy 101! :]

From a technical perspective, a single node is represented by the `SCNNode` class and represents a position in 3D space relative to its parent node. A node on its own has no visible content, therefore, it's invisible when rendered as part of a scene. To create visible content, you have to add other components such as lights, cameras or geometries (like bones) to the node.

The scene graph contains a special node which forms the foundation of your node-based hierarchy: the **root node**. To construct your scene, you add your nodes either as child nodes of the root node or as a child of one of the root node's descendants.

In this chapter, you'll start to work with a few simple nodes in SceneKit, such as camera and geometry nodes. By the end of the chapter, you'll have rendered a simple 3D cube to the screen!

Note: The next sections continue on using the project as you left it in Chapter 1. If you didn't follow along, no sweat — you can simply use the starter project for this chapter.

Asset catalogs

Once you're a successful and rich 3D game designer, you'll have enough money to hire your very own graphics artist and sound engineer, which will free you up to focus on the game code alone. :] The **SceneKit asset catalog** has been designed specifically to help you manage your game assets separately from the code.

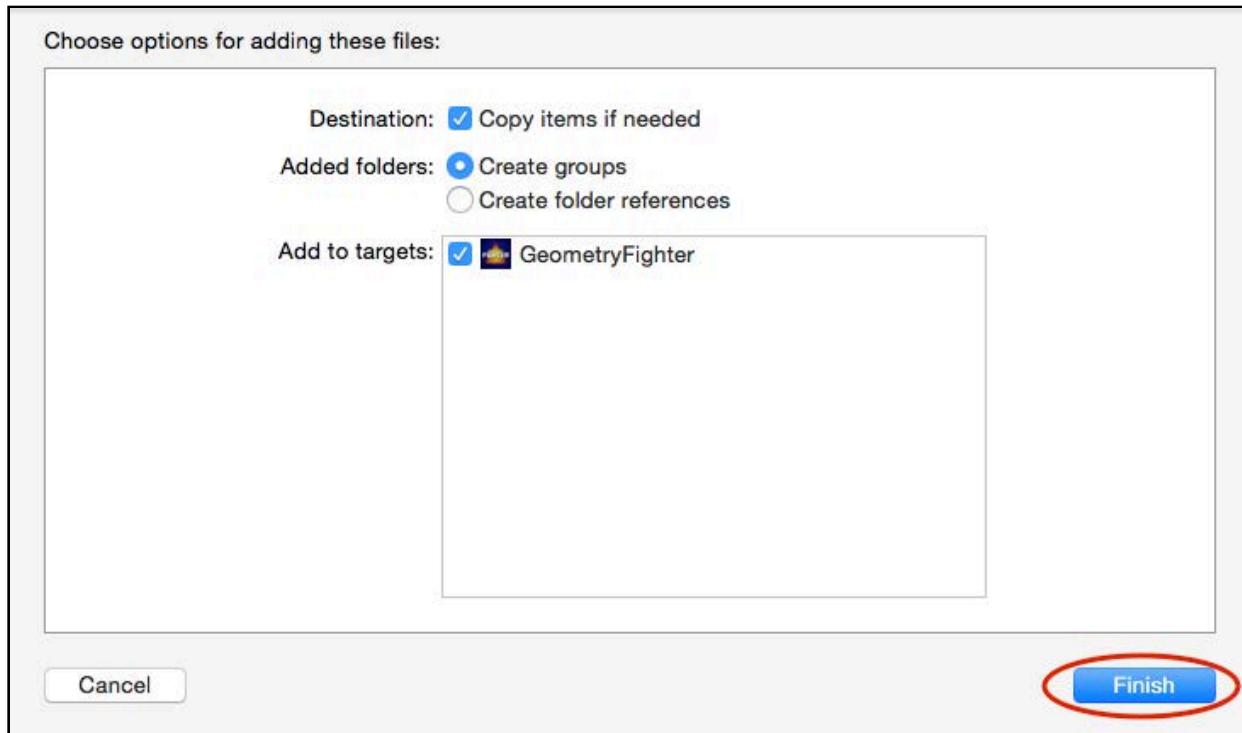
An asset catalog lets you manage your game assets in a single folder. To use it, simply add a folder with the `.scnassets` extension to your project and save all your game assets in that folder. Xcode will copy everything in your catalog to your app bundle at build time. Xcode preserves your assets folder hierarchy; this gives you full control over the folder structure.

By sharing your assets folder with your artists, they can quickly fix any issues, such as a not-quite-so-scary cross-eyed monster and have it ready for the next build, without having to copy the changed assets back into the project.

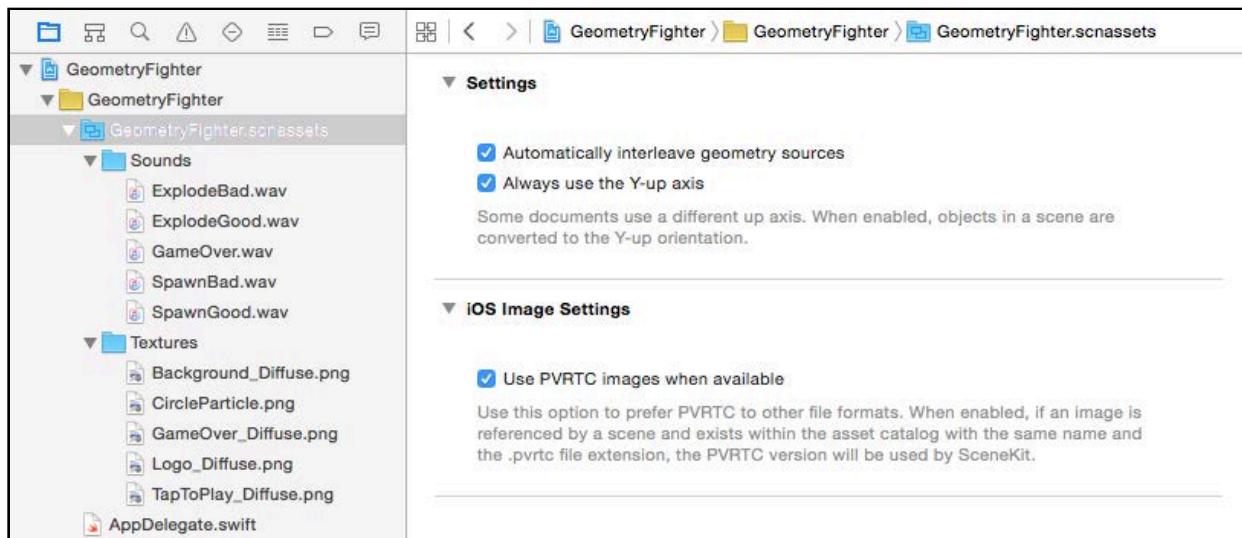
Adding an asset catalog

Now that you understand what the asset catalog is all about, you'll add one to Geometry Fighter.

Drag and drop the **GeometryFighter.scnassets** folder from the **resources** folder into your game project in Xcode. In the popup that appears, make sure that **Copy items if needed, Create Groups** and your **GeometryFighter** target are all checked, then click **Finish**.



Select the **GeometryFighter.scnassets** folder in the project navigator. Notice the additional settings unique to the asset catalog in the right hand panel. Expand the **GeometryFighter.scnassets** folder and sub-folders to see more detail about your assets:



There are two folders inside the asset catalog:

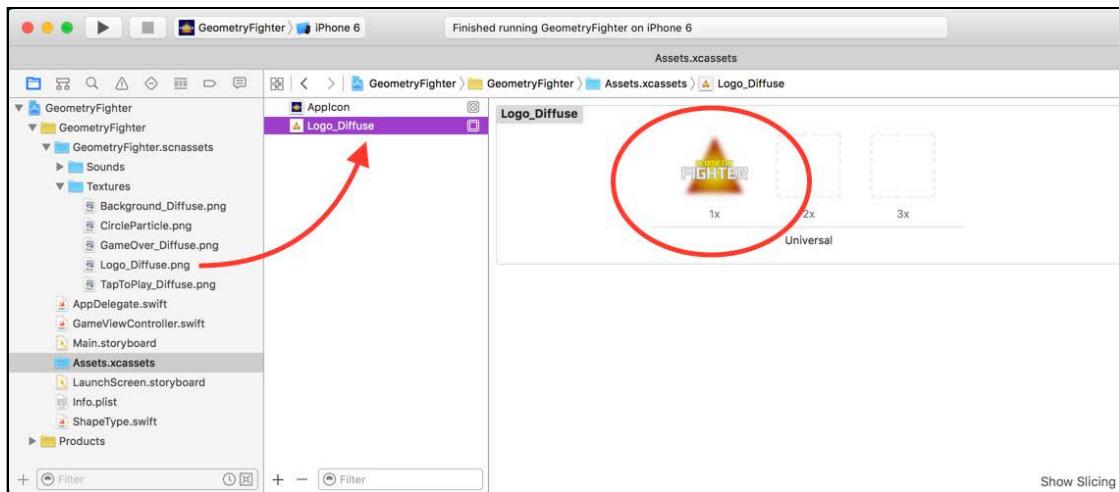
- **Sounds:** Contains all of the sound assets you'll need for your game.
- **Textures:** Contains all of the images you'll need.

Feel free to take a sneak peek at what's inside each folder.

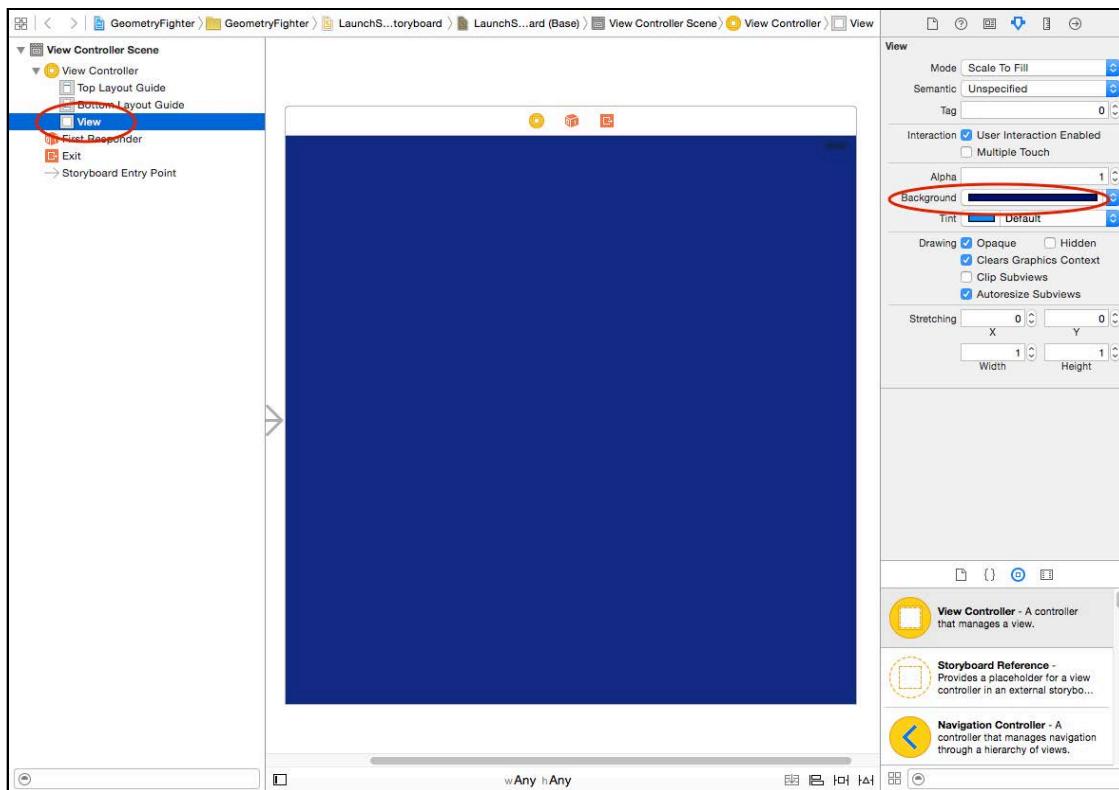
Adding a launch screen

Now that you've imported the asset catalog, you'll take care of some basic housekeeping steps, including adding a proper image to the launch screen.

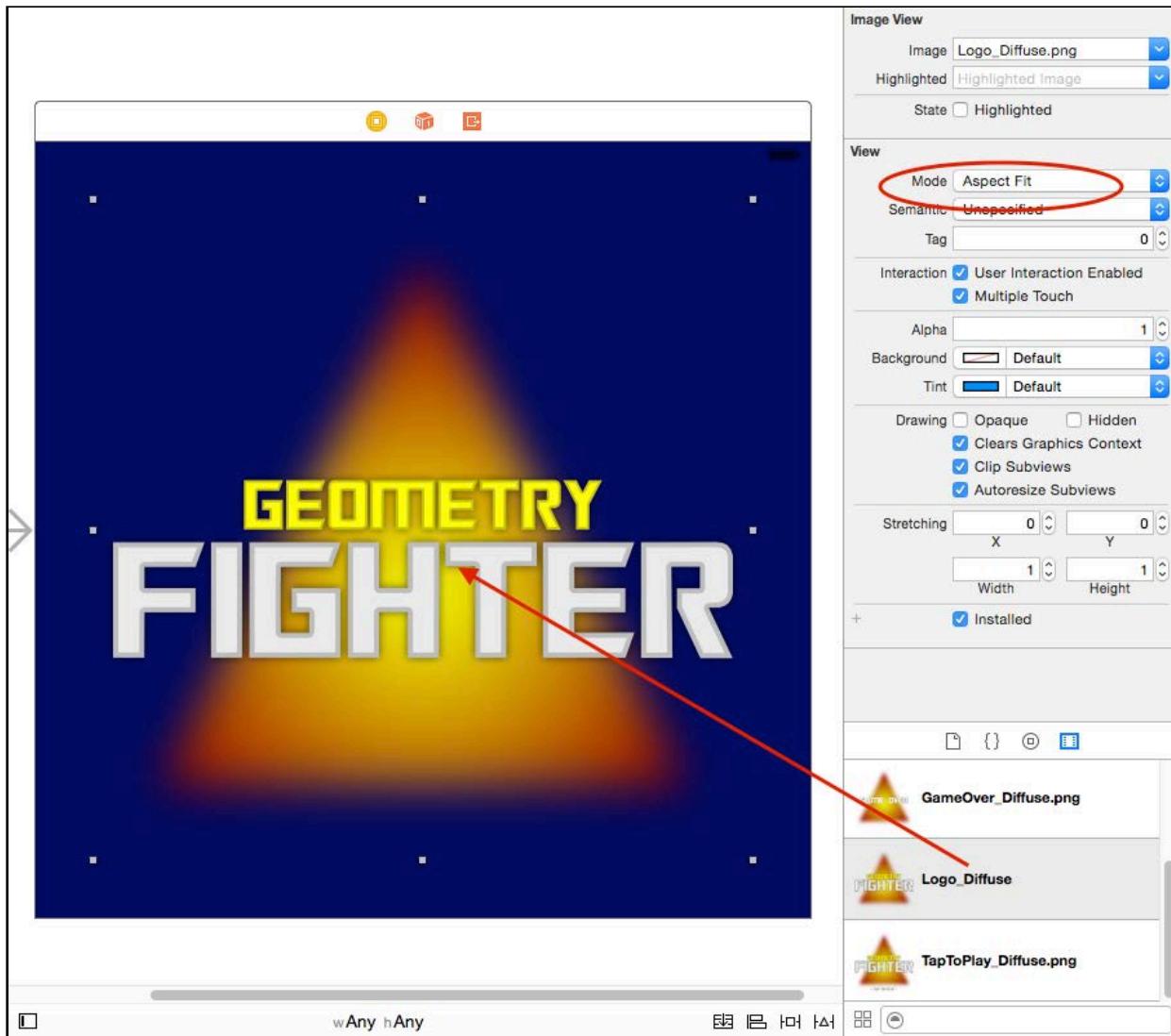
First, click **Assets.xcassets** in the project navigator. Drag and drop **GeometryFighter.scnassets/Textures/Logo_Diffuse.png** into the assets, below the **AppIcon**.



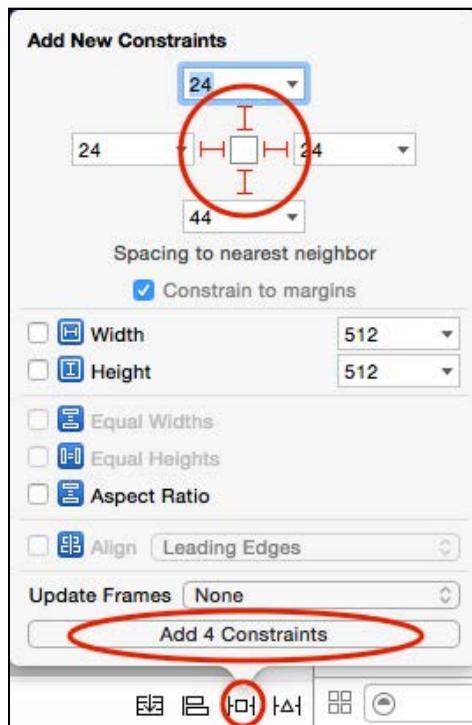
Next, click **LaunchScreen.storyboard** in the project navigator. Select the main view and set the **Background** property to a dark blue:



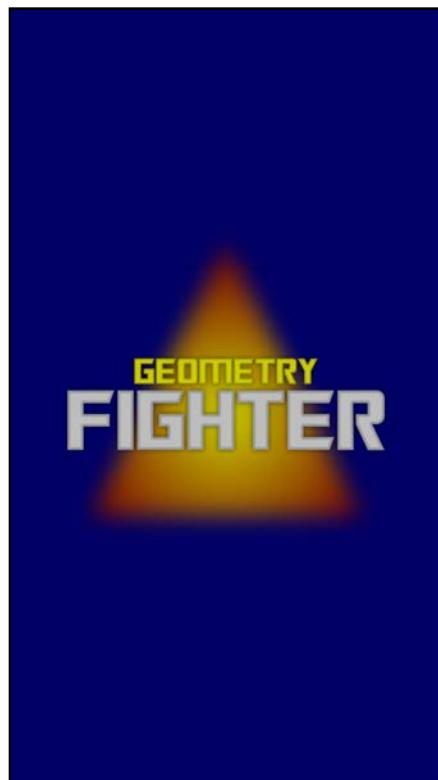
Next, drag the **Logo_Diffuse** image from the **Media Library** into the center of the view. Set the **Content Mode** property of your new image to **Aspect Fit**:



You're almost done with your launch screen. All you need to do is add some constraints so the splash image works on all devices. Click the **Pin** button at the bottom, toggle the constraints on for all four edges and click **Add 4 Constraints**.



You're done setting up your launch screen! Build and run your app; you'll see your shiny new launch screen appear:



Adding a background image

Once your splash screen disappears, you're dumped back to the blank screen of opportunity. Time to add a nice clean background so you don't feel like you're staring into a black hole.

To do this, add the following line of code to the bottom of `setupScene()` in **GameViewController.swift**:

```
scnScene.background.contents = "GeometryFighter.scnassets/Textures/  
Background_Diffuse.png"
```

This line of code instructs the scene to load the **Background_Diffuse.png** image from the asset catalog and use it as the material property of the scene's background.

Build and run; you should now see a blue background image once the game starts:



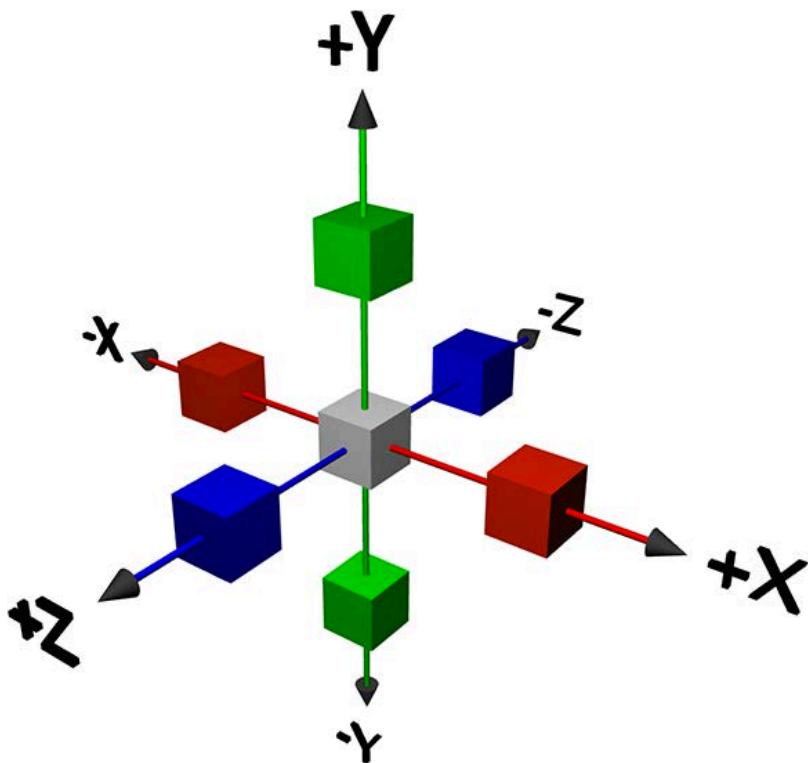
That's it! You've finished all the basic housekeeping tasks for your project. Your game now has a flashy app icon, a splash screen and a pretty background that's all ready to display the nodes you're about to add to the scene.

The SceneKit coordinate system

Before you can start adding nodes to the scene, you first need to understand how SceneKit's coordinate system works so you can position your nodes where you want them.

In a 2D system such as UIKit or SpriteKit, you use a point to describe the position of a view or a sprite on the x and y axes. To place an object in 3D space, you also need to describe the depth of the object's position on the z-axis.

Consider the following simple illustration:



SceneKit uses this three-axis system to represent position in 3D space. The red blocks are placed along the x-axis, the green blocks along the y-axis and the blue blocks along the z-axis. The grey cube in the very center of the axis indicates the **origin**, which has coordinates of (x:0, y:0, z:0).

SceneKit uses the SCNVector3 data type to represent coordinates in three dimensions as a three-component vector. Here's how you create a vector in code:

```
let position = SCNVector3(x: 0, y: 5, z: 10)
```

This declares the variable `position` with a vector of (x:0, y:5, z:10). You can easily access individual properties of the vector like so:

```
let x = position.x  
let y = position.y  
let z = position.z
```

If you've worked with `CGPoint` before, you can easily draw comparisons between it and `SCNVector3`.

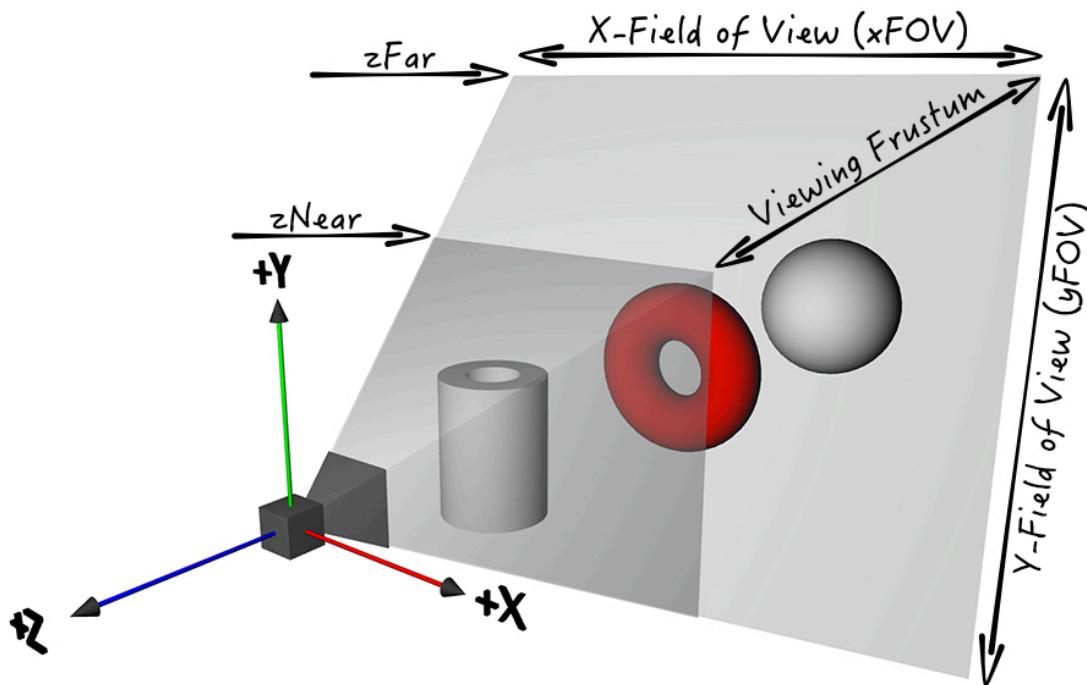
Note: Nodes added to the scene have a default position of `(x:0, y:0, z:0)`, which is always relative to the *parent* node. To place a node at the desired location, you need to adjust the position of the node relative to its parent (local coordinates) — not the origin (world coordinates).

Cameras

Now that you understand how to position nodes in SceneKit, you're probably wondering how to actually *display* something onscreen. Think back to the analogy of the movie set from Chapter 1. To shoot a scene, you'd position a camera looking at the scene and the resulting image of that scene would be from the camera's perspective.

SceneKit works in a similar fashion; the position of the node that contains the camera determines the point of view from which you view the scene.

The following illustration demonstrates how a camera works in SceneKit:



There are a few key points in the previous diagram:

- The camera's direction of view is always along the negative z-axis of the node that contains the camera.
- The **field of view** is the limiting angle of the viewable area of your camera. A tight angle provides a narrow view, while a wide angle provides a wide view.
- The **viewing frustum** determines the visible depth of your camera. Anything outside this area — that is, too close or too far from the camera — will be clipped and won't appear on the screen.

A SceneKit camera is represented by `SCNCamera`, whose `xPov` and `yPov` properties let you adjust the field of view, while `zNear` and `zFar` let you adjust the viewing frustum.

One key point to remember is that a camera by itself won't do anything unless it's a part of the node hierarchy.

Adding a camera

Time to try this out. Open `GameViewController.swift` and add the following property below `scnScene`:

```
var cameraNode: SCNNNode!
```

Next, add the following method below `setupScene()`:

```
func setupCamera() {
    // 1
    cameraNode = SCNNNode()
    // 2
    cameraNode.camera = SCNCamera()
    // 3
    cameraNode.position = SCNVector3(x: 0, y: 0, z: 10)
    // 4
    scnScene.rootNode.addChildNode(cameraNode)
}
```

Taking a closer look at the code:

1. First, you create an empty `SCNNNode` and assign it to `cameraNode`.
2. Next, you create a new `SCNCamera` object and assign it to the `camera` property of `cameraNode`.
3. Then, you set the position of the camera at `(x:0, y:0, z:10)`.
4. Finally, you add `cameraNode` to the scene as a child node of the scene's root node.

Finish things off by calling the method you just added in `viewDidLoad()`, right below `setupScene()`:

```
setupCamera()
```

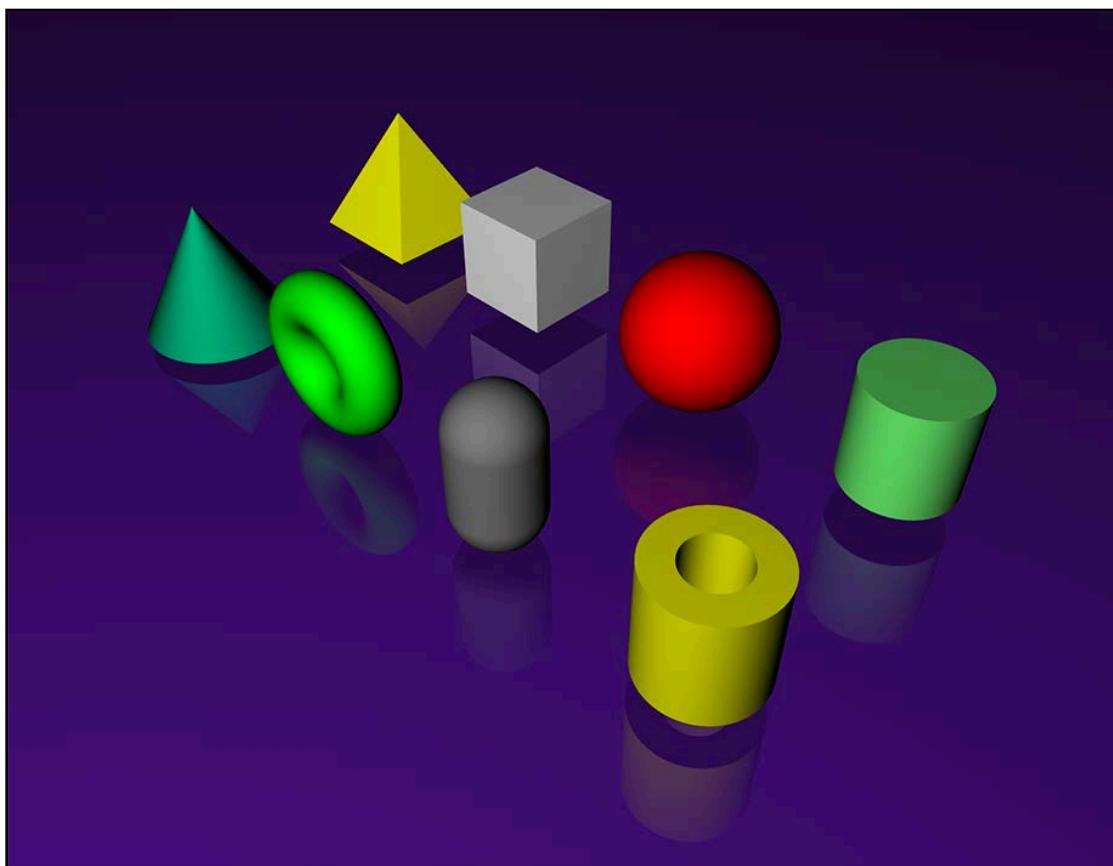
There is no need to build and run. Even though you just added a camera to the scene, there's still nothing to look at, which means you won't see anything different. But that's about to change!

Geometry

In order to create visible content, you need to add a geometry object to a node. A geometry object represents a three-dimensional shape and is created out of many points known as **vertices** that defines **polygons**.

Additionally, a geometry object can contain material objects that modify the appearance of a geometry's surface. Materials let you specify information such as the color and texture of the geometry's surface, and how the geometry should respond to light along with other visual effects. A collection of vertices and materials is known as a **model** or a **mesh**.

SceneKit includes the following built-in geometric shapes:



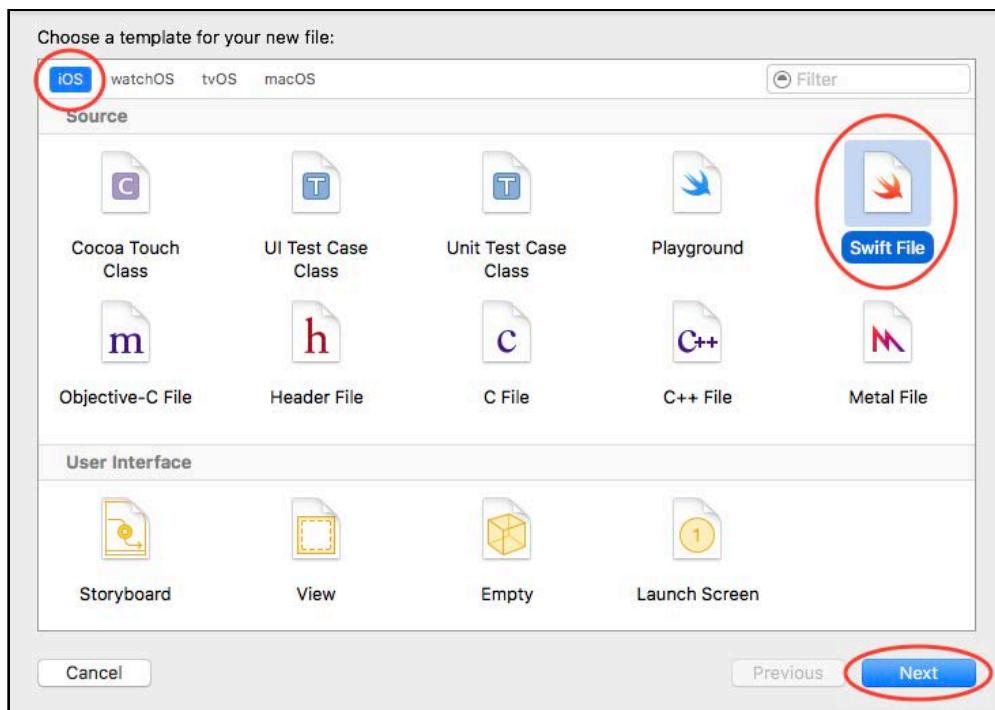
In the front row, starting from the left, you have a cone, a torus, a capsule and a tube. In the back row, again starting from the left, you have a pyramid, a box, a sphere and a cylinder.

Note: You can provide your own custom geometry data, but you'll cover this in later chapters.

Adding ShapeTypes

Before you start adding geometric shapes to the scene, create a new Swift file to define a **ShapeType** enum for the different shapes you'll use in the game.

Right-click on the **GeometryFighter** group and select **New File....** Select the **iOS/Source/Swift File** template and click **Next**:



Name the file **ShapeType.swift**, make sure it's included in your project, then click **Create**.

Once the file's been created, open **ShapeType.swift** and replace its contents with the following:

```
import Foundation

// 1
enum ShapeType:Int {

    case box = 0
    case sphere
```

```
case pyramid
case torus
case capsule
case cylinder
case cone
case tube

// 2
static func random() -> ShapeType {
    let maxValue = tube.rawValue
    let rand = arc4random_uniform(UInt32(maxValue+1))
    return ShapeType(rawValue: Int(rand))!
}
```

The code above is relatively straightforward:

1. You create a new enum named **ShapeType** that enumerates the various shapes.
2. You also define a static method named `random()` that generates a random **ShapeType**. This feature will come in handy later on in your game.

Adding a geometry node

Your next task is to create a method that spawns the various random shapes defined in **ShapeType**.

Add the following method to **GameViewController.swift**, right below `setupCamera()`:

```
func spawnShape() {
    // 1
    var geometry:SCNGeometry
    // 2
    switch ShapeType.random() {
    default:
        // 3
        geometry = SCNBox(width: 1.0, height: 1.0, length: 1.0,
                           chamferRadius: 0.0)
    }
    // 4
    let geometryNode = SCNNNode(geometry: geometry)
    // 5
    scnScene.rootNode.addChildNode(geometryNode)
}
```

Taking each numbered comment in turn:

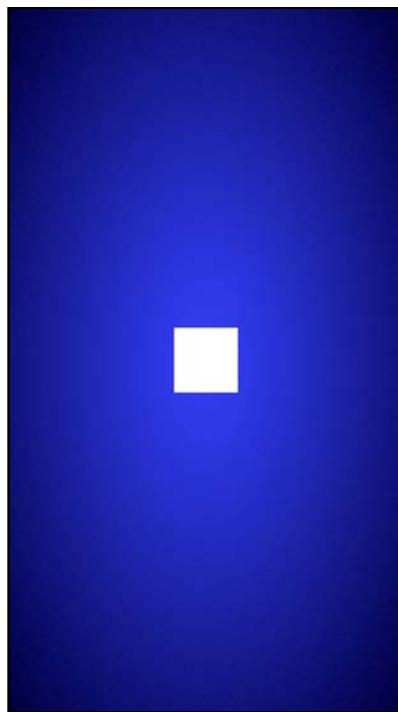
1. First, you create a placeholder `geometry` variable for use a bit later on.
2. Next, you define a `switch` statement to handle the returned shape from `ShapeType.random()`. It's incomplete at the moment, and only creates a box shape; you'll add more to it in the challenge at the end of this chapter.

3. Then, you create an SCNBox object and store it in geometry. You specify the width, height and length, along with the *chamfer radius* (which is a fancy way of saying rounded corners).
4. Here, you create an instance of SCNNODE named geometryNode. This time, you make use of the SCNNODE initializer which takes a geometry parameter to create a node and automatically attach the supplied geometry.
5. Finally, you add the node as a child of the scene's root node.

Now you need to call this method. Add the following line to `viewDidLoad()` below `setupCamera()`:

```
spawnShape()
```

Build and run; you'll see a white square displayed onscreen:



There are a few things to observe here:

- The box node is the default shape from `spawnShape()`, and it sits at `(x:0, y:0, z:0)` in the scene.
- You're viewing the scene through your `cameraNode`. Since the camera node lives at `(x:0, y:0, z:10)`, the box is smack dab in the center of the camera's viewable area.

OK, it's not very exciting, and it's hardly three-dimensional — but fear not... the next section changes all of that!

Built-in view features

SCNView comes with a few out-of-the-box features to help make your life easier.

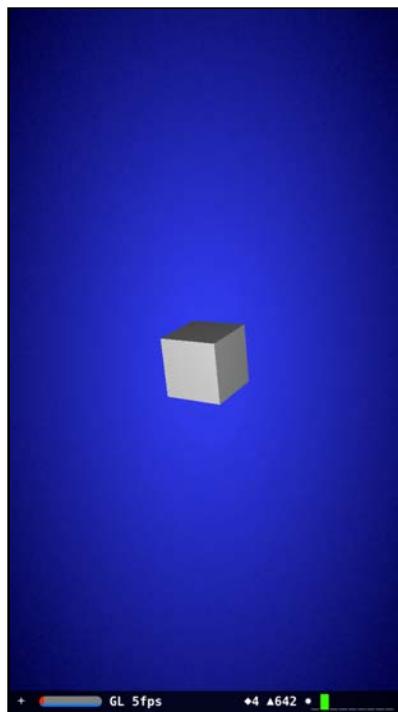
Add the following lines to `setupView()` in **GameViewController.swift**, just below the current implementation:

```
// 1  
scnView.showsStatistics = true  
// 2  
scnView.allowsCameraControl = true  
// 3  
scnView.autoenablesDefaultLighting = true
```

Here's an explanation of the code above:

1. `showsStatistics` enables a real-time statistics panel at the bottom of your scene.
2. `allowsCameraControl` lets you manually control the active camera through simple gestures.
3. `autoenablesDefaultLighting` creates a generic omnidirectional light in your scene so you don't have to worry about adding your own light sources.

Build and run; things should look a little more exciting this time around!



You can use the following gestures to control the active camera in your scene:

- **Single finger swipe:** Rotates your active camera around the contents of the scene.

- **Two finger swipe:** Moves, or *pans* your camera left, right, up or down in the scene.
- **Two finger pinch:** Zooms the camera in and out of the scene.
- **Double-tap:** If you have more than one camera, this switches between the cameras in your scene. Of course, since you have only one camera in the scene, this doesn't do that. However, it also has the effect of resetting the camera to its original position and settings.

Working with scene statistics

Find the statistics panel at the bottom of the screen:



Here's a quick breakdown of what each element means:

- **fps:** Stands for *frames per second*. This is a measurement of the total amount of consecutive frame redraws done in one-second. The lower this amount, the more poorly your game is performing. You typically want your game to run at 60fps, which will make your game look and feel smooth.
- **♦:** Stands for *total draw calls per frame*. This is typically the total amount of visible objects drawn per single frame. Lights affecting objects can also increase the amount of draw calls of an object. The lower this amount, the better.
- **▲:** Stands for *total polygons per frame*. This is the total amount of polygons used to draw a single frame for all the visible geometry. The lower this amount, the better.
- ***:** Stands for *total visible light sources*. This is the total amount of light sources currently affecting visible objects. The SceneKit guidelines recommend not using more than 3 light sources at a time.

Click on the **+** button to expand the panel and reveal more detail:



This panel provides you with the following information:

- **Frame time:** This is the total amount of time it took to draw a single frame. A *frame time* of 16.7ms is required to achieve a *frame rate* of 60fps.
- **The color chart:** This provides you with a rough frame time percentage breakdown per component within the SceneKit rendering pipeline.

From this example, you now know that it took 22.3ms to draw a single frame of which ±75% was used for *Rendering*, and ±25% was used for *GL Flush*.

Note: The SceneKit rendering pipeline will be discussed in more detail later on.

You can click the - button to minimize the panel again.

Isn't it great that all these features are built-in? :]

Challenges

It's important for you to practice what you've learned, on your own, so many chapters in this book have one or more challenges associated with them.

I highly recommend trying all of the challenges. While following a step-by-step tutorial is educational, you'll learn a lot more by solving a problem by yourself. In addition, each chapter will continue where the previous chapter's challenges left off, so you'll want to stay in the loop!

If you get stuck, you can find solutions in the resources for this chapter — but to get the most from this book, give it your best shot before you look!

Your first challenge

There's only one challenge in this chapter, but it's a fun one.

Your challenge is to improve the switch statement inside `spawnShape()` to handle the remaining shapes in the enumerator.

Use Apple's official SceneKit documentation (<http://apple.co/2aDBgtH>) as a guide to the various geometric shapes. Also, take a look at the `ShapeType` enum to see which shapes are left to create; their names should give you a good idea of where to start.

Don't worry too much about the sizes to use; just try to make them about the same relative size as the box you made earlier.

After this challenge, you'll have a firm grasp on some of the most fundamental concepts in SceneKit! :]

Where to go from here?

Congratulations, you've learned about quite a few concepts in this chapter:

- **Asset catalogs:** Helpful when managing your various game assets and working with your artists.
- **Coordinate system:** Now you know your up from your down, your left from your right — and most importantly, what backwards and forwards means in SceneKit.
- **Geometry:** You've covered the built-in primitive shapes in SceneKit and learned how to add geometry to a node to create visible content.
- **Skeleton Anatomy:** Quite possibly the most important thing you learned is how to identify a four-fingered skeleton — you never know when one might cross your path! :]

Now that you understand how nodes work in SceneKit, you'll bring them to life in the next chapter.

Chapter 3: Physics

Chris Language

Getting started

In this chapter, you'll use SceneKit's physics engine to add physics to your game.

SceneKit's physics engine is powerful, yet easy to use. You simply tell SceneKit on which objects you want to apply physics, and the engine will take over from that point, simulating things such as gravity and collisions.

Before you dive into integrating physics into your game, you'll first need to add some game utilities to your project.

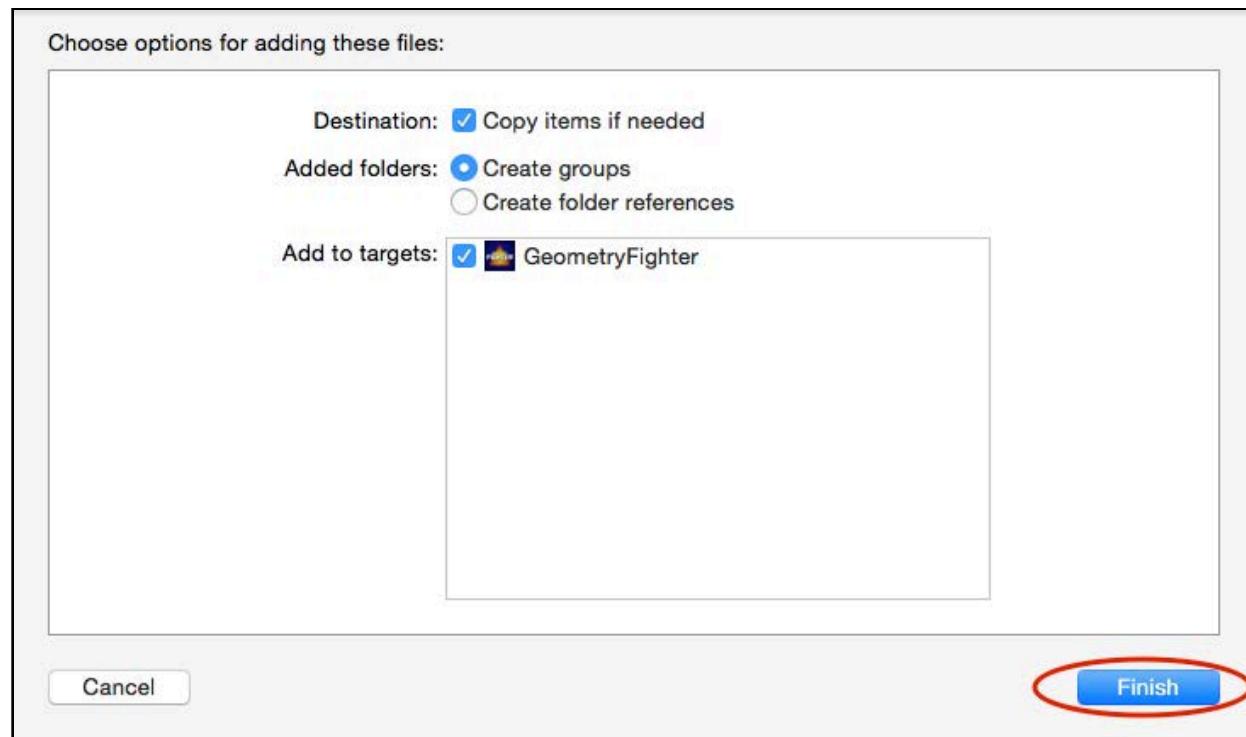
Note: This chapter's project continues on from the previous chapter. If you didn't follow along, or if you want to start fresh, you can find the starter project for this chapter under the **projects/starter/GeometryFighter** folder.

Introducing the game utilities

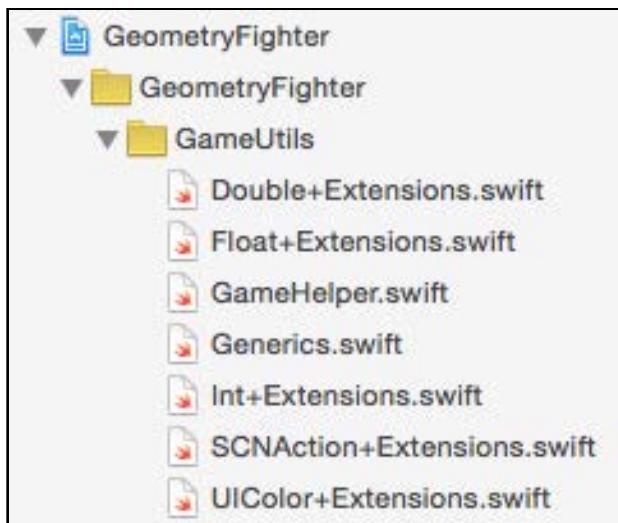
The game utilities were created especially for you. They include helper methods which handle the complicated bits in your game. This lets you focus on the gameplay rather than those pesky bits.

Adding the game utilities

To add the game utilities, simply drag and drop the **GameUtils** folder into your project under the **GeometryFighter** group folder:



Leave all the settings at their defaults and click **Finish**:



This imports the entire **GameUtils** folder into your project as a group. Expand this group folder and have a quick look at some of the helper methods. Don't worry too much if some of the code doesn't make sense to you yet.

Physics

Time for a quick status check of the current state of your game. Build and run the game; a cool random geometric object spawns out of thin air like some kind of dark magic. This might not seem like much right now, but things will definitely start to *shape* up soon! :]

The freshly spawned object just hangs there in an empty space and doesn't do much. Sure, you can rotate the camera around it and zoom in and out, but that's about it. It's not much of a fun game. To pump up the excitement level, it would be nice if the object at least moved around a little.

Now, you *could* take the long way around and manipulate the object's position and rotation over time so that it spins and moves around. You'd soon realize that although it's possible to animate objects in this manner, it requires a lot of coding effort — especially when you add into the mix other features like realistic collisions and interactions between objects.

Thankfully, the developers at Apple have already thought about this; to this end, they integrated a very powerful 3D physics engine into SceneKit. To make use of this built-in physics engine, you simply need to make the engine aware of your object.

In the same way you attach geometry information to your node, you can attach a **physics body** to your node. The physics body describes all the physical properties of your node, which includes things such as shape, mass, friction, damping and restitution. The physics engine takes all this information into account when it simulates the real-world physics interactions of your objects. This includes things such as gravity, friction and collisions with other bodies within the physics world.

The next section details some of the important characteristics of a physics body.

Physics body types

One of the key properties you must specify when creating a physics body is its **type**. The physics body type defines how the body interacts with forces and other bodies in the simulation.

There are three types used in SceneKit:

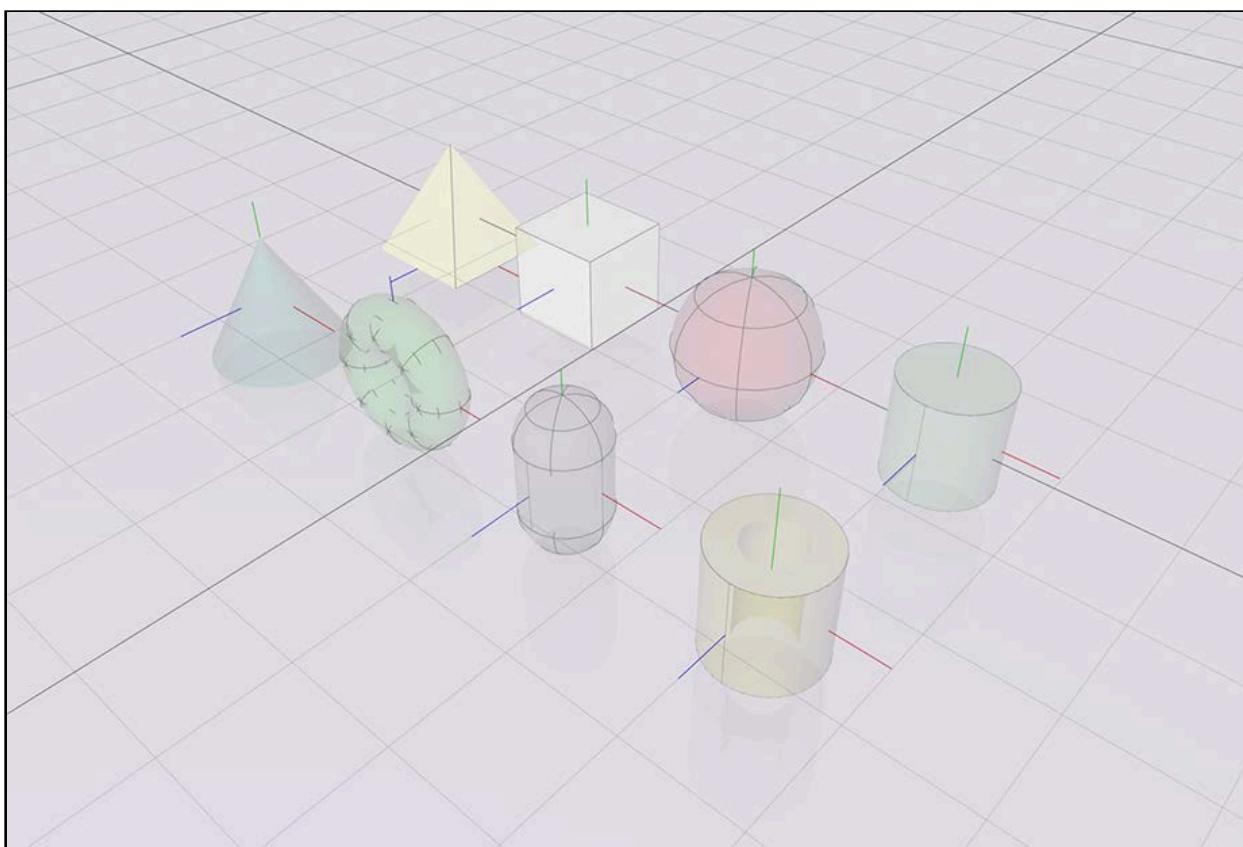
- **Static** bodies don't move: while other objects can collide with these bodies, the static bodies themselves are unaffected by any forces and collisions in the simulation. You can use this type for things like walls and massive immobile boulders.
- **Dynamic** bodies are automatically moved by the physics engine in response to forces and collisions. You can use this type for things such as movable chairs, tables and cups.

- **Kinematic** bodies are **not** automatically moved by the physics engine in response to forces and collisions. In other words, if a kinematic body collides with a dynamic body, the dynamic body will move, but the kinematic body won't. However, you can move kinematic bodies around manually in code. You can use this type for things you want to control manually, such as moving elevators or a door that can open and close.

Physics shapes

In addition to the type of the body, another import property you must specify when creating a physics body is its **shape**. The physics shape defines the 3D shape used by the physics engine during collision detections. While the geometry defines the *visuals* of the node, the physics body defines how the node *interacts* with other objects in a physics simulation.

You can make the shape exactly the same as the visual geometry, but this is often more computationally expensive than you need (hence causing your game to run slower). Instead, you should usually work with a simplified version of the geometry for your shape, such as a simple bounding box, sphere or one of the provided primitive shapes that roughly matches the node's visible appearance like so:



Adding physics

Now that you've learned the theory behind the physics, it's time to start using these concepts to move things around in your game.

In SceneKit, all the physics bodies are `SCNPhysicsBody` objects. Once you create the physics body, you can assign it to the `physicsBody` property of the `SCNNode` instance. Once you assign the physics body to the appropriate node, the physics engine can simulate the physics for you. It's that simple! :]

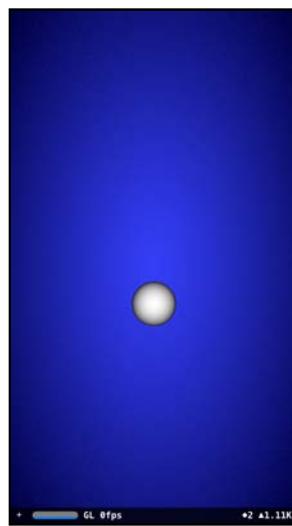
Open `GameViewController.swift` and add the following after the line of code that creates `geometryNode` in `spawnShape()`:

```
geometryNode.physicsBody =  
    SCNPhysicsBody(type: .dynamic, shape: nil)
```

This line of code creates a new instance of `SCNPhysicsBody` and assigns it to the `physicsBody` property of `geometryNode`. When you create a physics body, you specify the type and shape of the body. If you pass in `nil` for the physics shape, SceneKit will automatically generate a shape based on the visual geometry of the node. Neat, huh?

If you want to add more detail to the physics shape, you can create a `SCNPhysicsShape` and use that for the shape instead of passing in `nil`.

Build and run your game; a random shape spawns into the scene, and then drops out of the air with all the grace of a dead bird, falling out of sight:



You can even pan the camera to watch the object fall into oblivion. What you're witnessing here is the effect of gravity acting on the object. A scene in SceneKit has gravity turned on by default. Now that the spawned object has a physics body, the physics simulation will apply simulated forces — such as gravity — to the object.

Forces

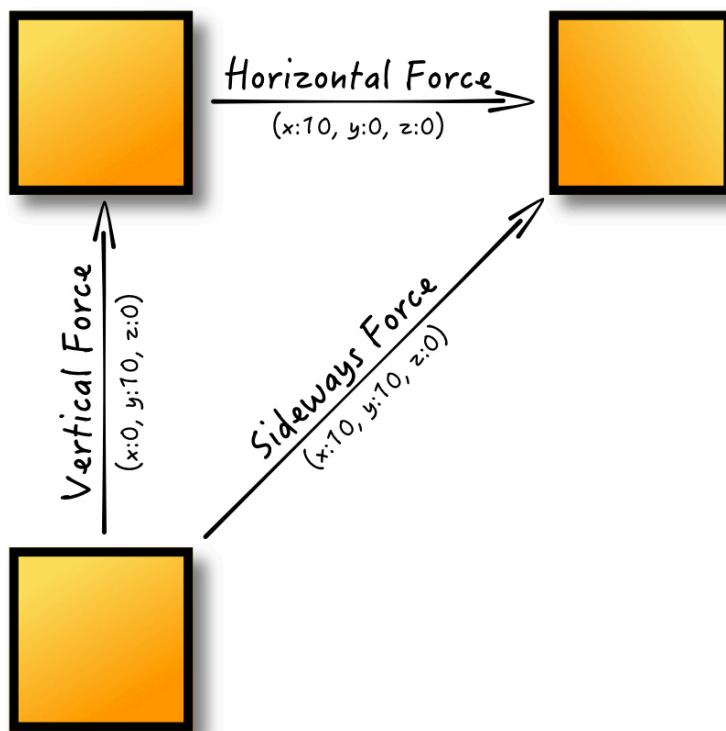
Think about objects in real life for a moment: to make something move — such as a spoon on top of a table — you have to apply some type of physical force on it. Unless you're living inside the Matrix, your name is Neo and there isn't even an actual spoon to begin with. :]

The SceneKit physics engine does a pretty good job mimicking real-life physics, so just as you'd apply a force to move an object in real life, you'll need to apply a force on your physics body to move it around.

When you apply a force to a physics body, you use `applyForce(direction: at: asImpulse:)` and pass in an instance of `SCNVector3` for both the force and the position where you want to apply that force, along with whether the force should be applied as an impulse. The force you apply affects both the linear and angular acceleration of the physics body.

An impulse applies the force only once to the physics body, such as when you kick a ball. Forces that *aren't* impulses are applied at each step in the physics simulation. SceneKit will add up all applied forces on the object and accelerate the physics body according to the net result of those forces. This can simulate something like a booster rocket, where the force is continuous.

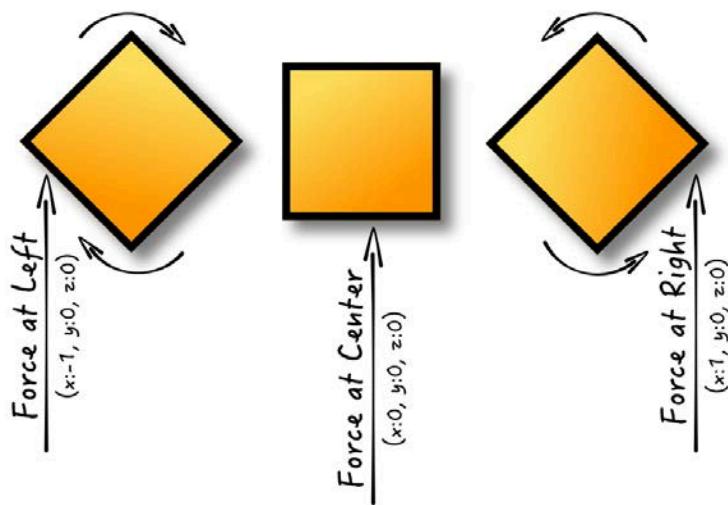
Earlier, you learned that a force is a vector with an x, y and z component. But what does that mean? Take a look at the following diagram.



A force has both magnitude and direction, so the vector determines the magnitude of the force for each individual axis. In the example above, applying a force with a vector of $(x:0, y:10, z:0)$ moves the body upwards with a vertical force.

To apply a horizontal force, you would only specify the magnitude of the force on the x axis using a vector of $(x:10, y:0, z:0)$. To move the body left instead of right, you would apply a negative magnitude of force on the x axis. When you combine various vectors together like $(x:10, y:10, z:0)$, you can control exactly how you want the body to move — in this case, diagonally.

Forces can also be applied at a specific position on a physics body to produce different movements:



Again, it helps to think of real-life examples. If you had a block in front of you and pushed it, the block would move differently depending on the spot you applied the push. Applying the same force to the left or right of the body's center of mass, for example, at $(x:1, y:0, z:0)$ would cause it to spin. Applying the force directly in line with the center of mass at $(x:0, y:0, z:0)$ wouldn't produce a spin.

Applying force

Roll up your sleeves — it's time to apply some force! :]

Add the following code after the line where you create the physics body for `geometryNode` inside `spawnShape()`:

```
// 1
let randomX = Float.random(min: -2, max: 2)
let randomY = Float.random(min: 10, max: 18)
// 2
let force = SCNVector3(x: randomX, y: randomY, z: 0)
// 3
let position = SCNVector3(x: 0.05, y: 0.05, z: 0.05)
// 4
```

```
geometryNode.physicsBody?.applyForce(force,  
at: position, asImpulse: true)
```

Taking each commented line in turn:

1. This creates two random float values that represent the x- and y-components of the force. It uses an extension on `Float` from the utilities you added earlier in this chapter.
2. Next, you use those random components to create a vector to represent this force.
3. This creates another vector that represents the position to which the force will be applied. The position is slightly off-center so as to create a spin on the object.
4. Finally, using all those components, you apply the force to `geometryNode`'s physics body using `applyForce(direction: at: asImpulse:)`.

Build and run; as the object spawns out of thin air, some magical force kicks it up into the air instead of dropping like a dead bird:

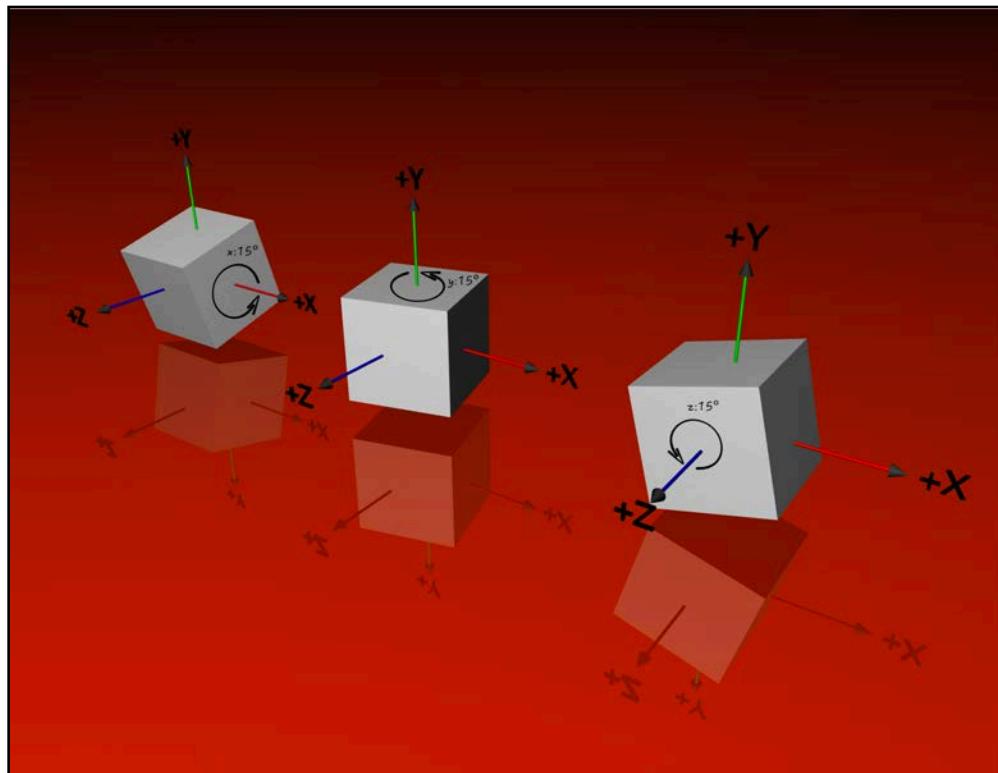


As gravity takes its toll, the object eventually falls back down.

Torque

Torque is another rotational force you can apply to a body using `applyTorque(torque: asImpulse:)`. Torque only affects the angular momentum (spin) of the physics body, not the linear momentum (x, y, z). Applying torque causes an object to spin around its center of mass.

To see how torque affects a physics body, take a look at the following illustration:



When applying a torque force, you specify a four-component vector using `SCNVector4` rather than a three-component vector as you do with forces. The x-, y- and z-components determine the rotation axis, while the w-component determines the rotation angle, that is, the magnitude of the torque.

Just as you do with `applyForce(direction: at: asImpulse:)`, you can choose whether or not to apply the torque as an impulse, which affects how the physics engine treats the vector.

If the torque is an impulse, the directional vector is treated as an instantaneous change in the angular momentum. Think of spinning a basketball on your finger; to keep the ball spinning, you have to quickly flick the side of the ball with your hand, which applies an impulse with each flick that instantaneously increases the angular momentum of the ball.

When a torque is not applied as an impulse, it's applied after each physics simulation step. SceneKit will sum all applied forces and torques, and accelerate the angular force of the physics body according to the net effect of those forces. Think of this as a planet spinning at a constant speed around its own axis.

Note: The SceneKit physics simulation uses the International System of Units (SI) for measurements: **Kilograms** for units of mass, **Newtons** for units of force, **Newton-second** for units of impulse, and **Newton-meter** for units of torque.

Adding flair

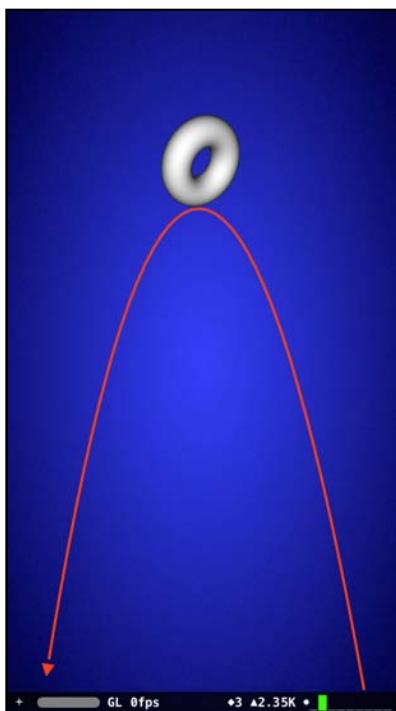
Now that you've got your geometric object moving, you may have noticed it spawns out of thin air right in the middle of the screen, which looks a bit awkward. To fix that, you'll shift the camera on the y-axis a bit so that the object spawns off-screen.

Positioning the camera

To move the camera position up, replace the line where you set the camera's position in `setupCamera()` with the following:

```
cameraNode.position = SCNVector3(x: 0, y: 5, z: 10)
```

Build and run, and you'll see that the object appears to spawn off-screen!



Adding some color

As a final touch, you'll add a bit of variety to your randomly generated shapes.

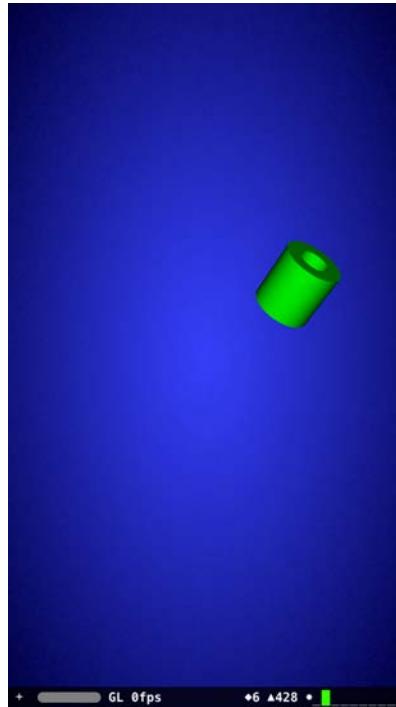
Add the following lines inside `spawnShape()`, after the spot where you randomly create geometry, but just before you create `geometryNode`:

```
geometry.materials.first?.diffuse.contents = UIColor.random()
```

To color your random object, you modify materials on `geometry`; this line gets the first available material of `geometry` and sets the `diffuse` property's contents to a random `UIColor`. The `random()` method on `UIColor` is another helper defined as an extension inside the game utilities.

Note: You'll learn more about materials and their properties in Section II of this book. The takeaway here is that you can assign a `UIColor` to the `diffuse` property's content in order to change the object's color.

Finally, build and run your game to see a beautifully colored object:



Wouldn't it be neat if you could spawn more than one object? You'll fix this...in the next chapter! :]

Where to go from here?

You're making excellent progress, and you're more than halfway through your first SceneKit game! If you're flexible (unlike me), give yourself a pat on the back.

In this chapter, you learned a number of things about:

- **SceneKit's physics engine** and how to leverage it for object animation.
- **Physics bodies** and how to attach them to a node to recreate real-world object behavior.
- **Physics shapes**, how to define them and how to efficiently use simplified shapes for your complex geometry.
- **Forces and impulses** and how to use them to create linear and angular movement.

There's no challenge for this chapter. But keep reading, because in the next chapter, you'll learn how to spawn multiple objects through the power of the render loop!

Chapter 4: Render Loop

Chris Language

Getting started

In the previous chapter, you enabled basic physics for your spawned object and applied an impulse to kick it up into the air. Eventually, the object fell back down and vanished into the abyss due to the simulated effect of gravity.

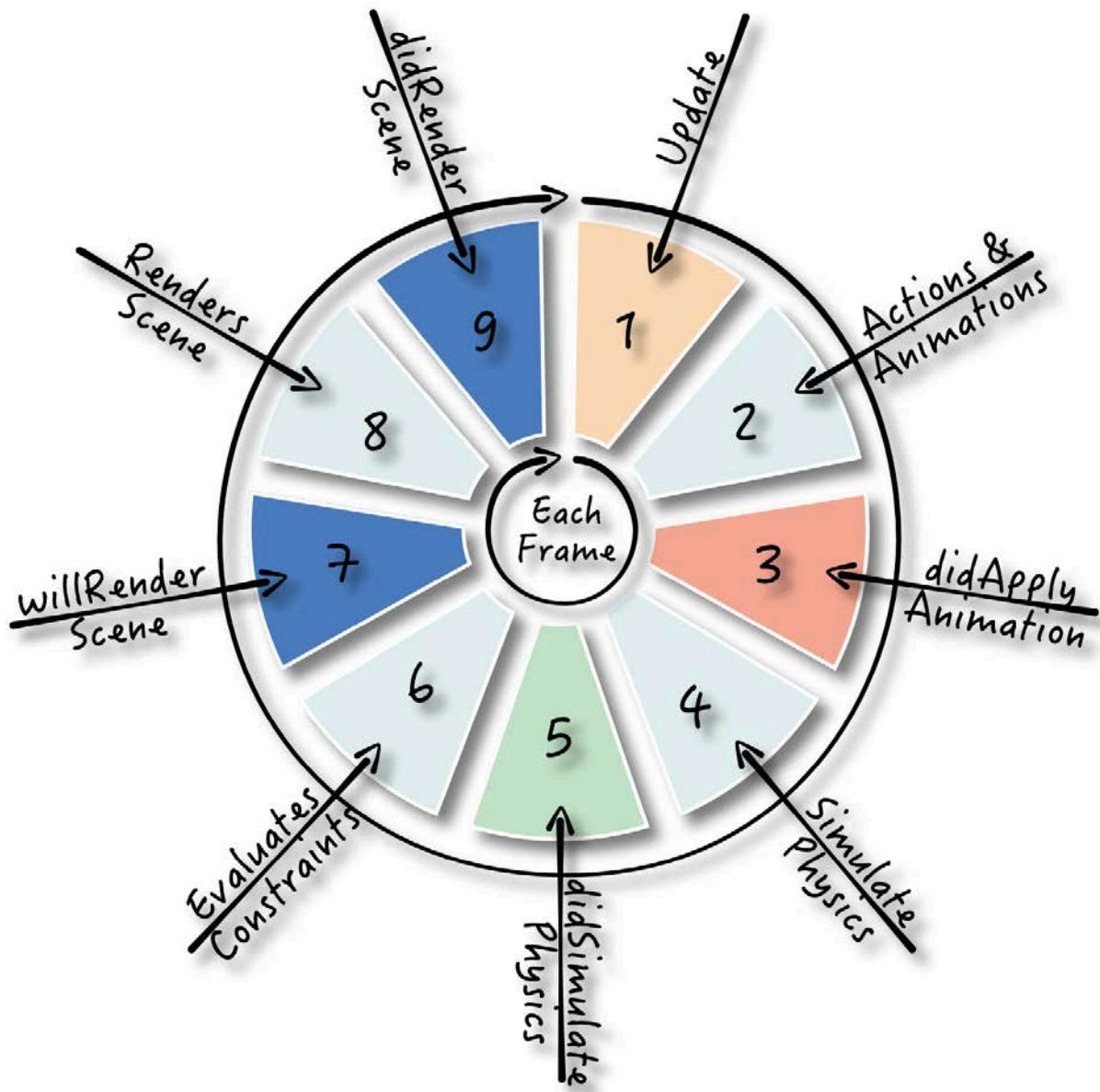
Although the effect is neat, it would be *so* much cooler to spawn multiple objects that collide with each other. This will certainly push the excitement factor up a notch!

Right now, your game calls `spawnShape()` just once. To spawn multiple objects you'll need to call `spawnShape()` repeatedly. Introducing... the **render loop**!

As you learned in previous chapters, SceneKit renders the contents of your scene using an `SCNView` object. `SCNView` has a delegate property that you can set to an object that conforms to the `SCNSceneRendererDelegate` protocol; `SCNView` will then call methods on that delegate when certain events occur within the animation and rendering process of each frame.

In this way, you can tap into the steps SceneKit takes as it renders each frame of a scene. These rendering steps are what make up the *render loop*.

So — what exactly *are* these steps? Well, here's a quick breakdown of the render loop:



Is this *Wheel of Fortune*? :] No, it's simply a depiction of the nine steps of the render loop. In a game that runs at 60 fps, all these steps run — you guessed it — 60 times per second, in sequence.

The steps always execute in the following order, which lets you inject your game logic exactly where it's needed:

1. **Update:** The view calls `renderer(_: updateAtTime:)` on its delegate. This is a good spot to put basic scene update logic.

2. **Execute Actions & Animations:** SceneKit executes all actions and performs all attached animations to the nodes in the scene graph.
3. **Did Apply Animations:** The view calls its delegate's `renderer(_:didApplyAnimationsAtTime:)`. At this point, all the nodes in the scene have completed one single frame's worth of animation, based on the applied actions and animations.
4. **Simulates Physics:** SceneKit applies a single step of physics simulation to all the physics bodies in the scene.
5. **Did Simulate Physics:** The view calls `renderer(_:didSimulatePhysicsAtTime:)` on its delegate. At this point, the physics simulation step has completed, and you can add in any logic dependent on the physics applied above.
6. **Evaluates Constraints:** SceneKit evaluates and applies constraints, which are rules you can configure to make SceneKit automatically adjust the transformation of a node.
7. **Will Render Scene:** The view calls `renderer(_:willRenderScene:atTime:)` on its delegate. At this point, the view is about to render the scene, so any last minute changes should be performed here.
8. **Renders Scene In View:** SceneKit renders the scene in the view.
9. **Did Render Scene:** The final step is for the view to call its delegate's `renderer(_:didRenderScene:atTime:)`. This marks the end of one cycle of the render loop; you can put any game logic in here that needs to execute before the process starts anew.

Because the render loop is, well, a *loop*, it's the perfect place to call `spawnShape()`. Your job is to decide where to inject the spawn logic.

The renderer delegate

It's time to put this cool feature to use in your game.

First, make the `GameViewController` class conform to the `SCNSceneRendererDelegate` protocol by adding the following to the bottom of `GameViewController.swift`:

```
// 1
extension GameViewController: SCNSceneRendererDelegate {
    // 2
    func renderer(_ renderer: SCNSceneRenderer,
                 updateAtTime time: TimeInterval) {
        // 3
        spawnShape()
    }
}
```

Taking a closer look at the code above:

1. This adds an extension to GameViewController for protocol conformance and lets you maintain protocol methods in separate blocks of code.
2. This adds an implementation of the renderer(_: updateAtTime:) protocol method.
3. Finally, you call spawnShape() to create a new shape inside the delegate method.

This gives you your first hook into SceneKit's render loop. Before the view can call this delegate method, it first needs to know that GameViewController will act as the delegate for the view.

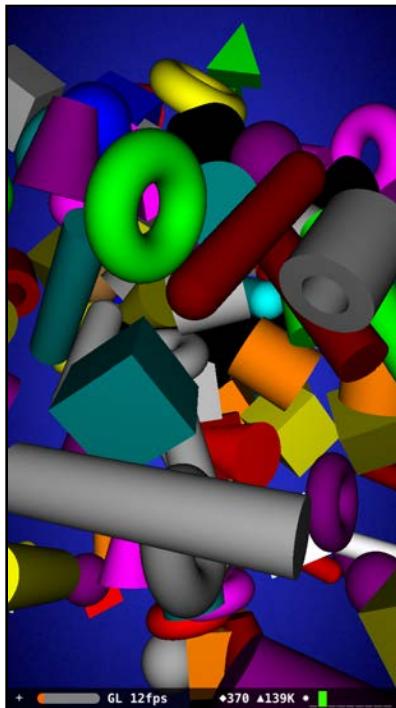
Do this by adding the following line to the bottom of setupView():

```
scnView.delegate = self
```

This sets the delegate of the SceneKit view to `self`. Now the view can call the delegate methods you implement in GameViewController when the render loop runs.

Finally, clean up your code a little by removing the single call to `spawnShape()` inside `viewDidLoad()`; it's no longer needed since you're calling the method inside the render loop now.

Build and run; unleash the spawning fury of your render loop! :]



The game starts and spawns an insane amount of objects, resulting in a mosh pit of colliding objects — awesome! :]

So what's happening here? Since you're calling `spawnShape()` in every update step of the render loop, you'll spawn 60 objects per second — if the device you're running on can support your game at 60 fps. But less-powerful devices, which includes the simulator, can't support that frame rate.

As the game runs, you'll notice a rapid decrease in the frame rate. Not only does the graphics processor have to deal with increasing amounts of geometry, the physics engine has to deal with an increasing number of collisions, which also negatively affects your frame rate.

Things are a bit out of control at the moment, as your game won't perform terribly well on all devices.

Spawn timers

To make the gaming experience consistent across devices, you need to make use of **time**. No, I don't mean taking more time to write your game! :] Rather, you need to use the passage of time as the one constant across devices; this lets you animate at a consistent rate, regardless of the frame rate the device can support.

Timers are a common technique in many games. Remember the `updateAtTime` parameter passed into the `update` delegate method? That parameter represents the current system time. If you monitor this parameter, you can calculate things like the elapsed time of your game, or spawn a new object every three seconds instead of as fast as possible.

Geometry Fighter will use a simple timer to spawn objects at randomly timed interval that any processor should be able to handle.

Add the following property to `GameViewController` below `cameraNode`:

```
var spawnTime: TimeInterval = 0
```

You'll use this to determine time interval until you spawn another shape.

To fix the continuous spawning, replace the entire body of `renderer(_:_)` with the following:

```
// 1
if time > spawnTime {
    spawnShape()

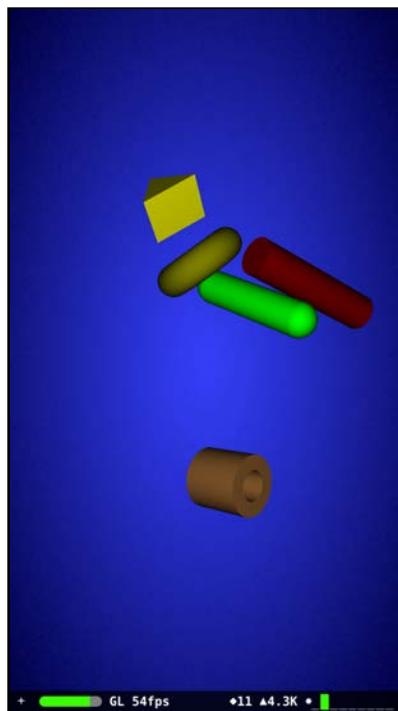
// 2
    spawnTime = time + TimeInterval(Float.random(min: 0.2, max: 1.5))
}
```

Taking each commented line in turn:

1. You check if `time` (the current system time) is greater than `spawnTime`. If so, spawn a new shape; otherwise, do nothing.

- After you spawn an object, update `spawnTime` with the *next* time to spawn a new object. The next spawn time is simply the current time incremented by a random amount. Since `TimeInterval` is in seconds, you spawn the next object between 0.2 seconds and 1.5 seconds after the current time.

Build and run; check out the difference your timer makes:



Mesmerizing, eh?

Things look a bit more manageable, and the shapes are spawning randomly. But aren't you curious about what happens to all those objects after they fall out of sight?

Removing child nodes

`spawnShape()` continuously adds new child nodes into the scene — but they're never removed, even after they fall out of sight. SceneKit does an awesome job of keeping things running smoothly for as long as possible, but that doesn't mean you can forget about your children. What kind of parent are you? :]

To run at an optimal performance level and frame rate, you'll have to remove objects that fall out of sight. And what better place to do this than — that's right, the render loop! Handy thing, isn't it?

Once an object reaches the limits of its bounds, you should remove it from the scene.

Add the following to the end of your GameViewController class, right below spawnShape():

```
func cleanScene() {  
    // 1  
    for node in scnScene.rootNode.childNodes {  
        // 2  
        if node.presentation.position.y < -2 {  
            // 3  
            node.removeFromParentNode()  
        }  
    }  
}
```

Here's what's going on in the code above:

1. First, you simply create a little `for` loop that steps through all available child nodes within the root node of the scene.
2. Since the physics simulation is in play at this point, you can't simply look at the object's position as this reflects the position *before* the animation started. SceneKit maintains a copy of the object during the animation and plays it out until the animation is done. It's a strange concept to understand at first, but you'll see how this works before long. To get the actual position of an object while it's animating, you leverage the `presentationNode` property. This is purely read-only — don't attempt to modify any values on this property!
3. This line of code makes an object blink out of existence; it seems cruel to do this to your children, but hey, that's just tough love.

To use your method above, add the following line to call `cleanScene()` just after the `if` statement inside `renderer(_: updatedAtTime:)`:

```
cleanScene()
```

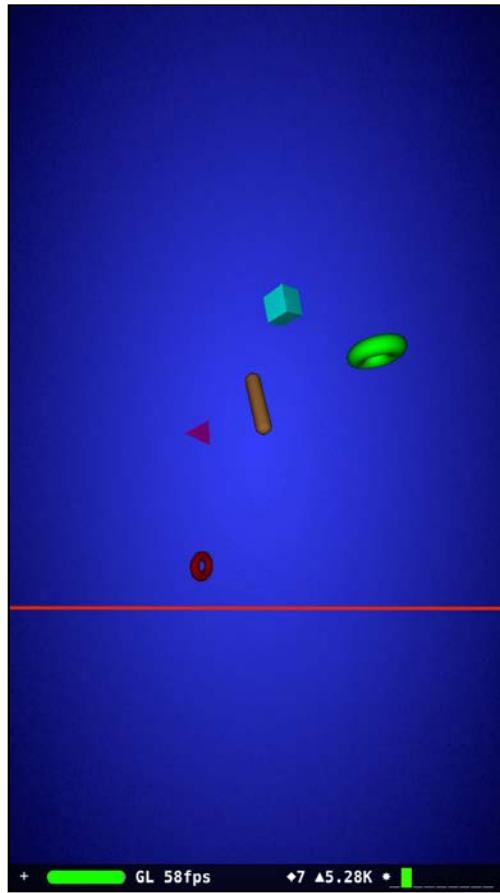
There's one last thing to add. By default, SceneKit enters into a "paused" state if there are no animations to play out. To prevent this from happening, you have to enable the `playing` property on your `SCNView` instance.

Add the following line of code to the bottom of `setupView()`:

```
scnView.isPlaying = true
```

This forces the SceneKit view into an endless playing mode.

Build and run; as your objects start to fall, pinch to zoom out and see where they disappear into nothingness:



Objects that fall past the lower y-bound (noted by the red line in the screenshot above), are removed from the scene. That's better than having all those objects lying around the dark recesses of your device. :]

Where to go from here?

You're making good progress on your game; the finish line is in sight and there's only one more chapter in this section!

This chapter covered some fairly complex SceneKit concepts:

- **The render loop:** You learned about the nine steps of the render loop, and you know you can inject game logic at certain points using `SCNSceneRendererDelegate`.
- **Timers:** You learned how to use time to make your game behave consistently across devices.

- **presentationNode:** You learned that all nodes under animation have a “copied” version called the presentationNode. You also learned that you can read real-time information from this node while the animation plays.
- **removeFromParentNode.** You learned how to be a responsible parent and remove children nodes that are no longer needed.

Again, there's no challenge this time, so keep reading to spice up your game through the power of particle systems!

Chapter 5: Particle Systems

Chris Language

Getting started

Picture yourself in the movie theatre, popcorn in hand; on the screen, a bad guy from *The Fast and the Furious* smashes his roaring, high-performance dragster into a highly volatile fuel tanker which explodes in a massive fireball of death and carnage. Yeah! :]

Now, think of that same scene, but without the massive fireball explosion. You can almost feel the collective disappointment of audiences around the world. :[

Just like a Hollywood blockbuster, your game needs special effects to amp up the excitement level. These special effects come in the form of what's known as **particle systems**. You can use particle systems for a multitude of effects, from moving star fields, to burning rocket boosters, to rain and snow, to metal sparks — and yes, even massive exploding fireballs!

It's time to take a look at how you can add some of these neat special effects to Geometry Fighter.

Particle systems

In SceneKit, `SCNParticleSystem` manages the creation, animation and removal of particles from the scene graph.

A *particle* is essentially a small image sprite. The particle system doesn't add the individual particles into the scene graph itself, so you don't have direct access to each particle; the particle system manages the particles, including their look, size and location.

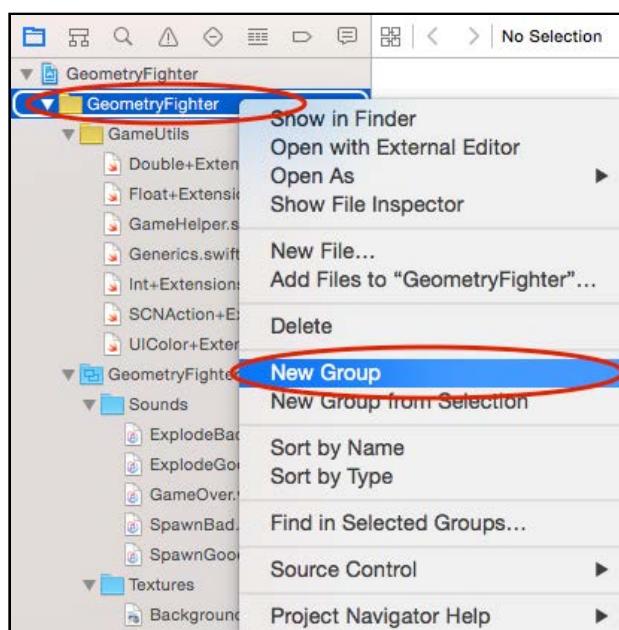
However, you can influence the particle system by modifying various properties on it, such as:

- **Appearance:** Each particle of the system can be rendered as a single image, or an animated sequence of images. You can adjust the size, tint color, blending mode and other rendering parameters of the particles generated.
- **Life Span:** The system uses a **particle emitter**, which gives birth to each individual particle. The lifespan of the particle determines how long it stays visible in the scene.
- **Emitter behavior:** You can control various parameters of the emitter, such as where particles spawn and the spawn rate.
- **Variation:** Introducing variations into your particle system can make it look more, or less, random.
- **Movement:** You can adjust how particles move once they've spawned. Particles use a simplified physics simulation to speed up performance, but the particles can still interact with objects managed by the physics engine.

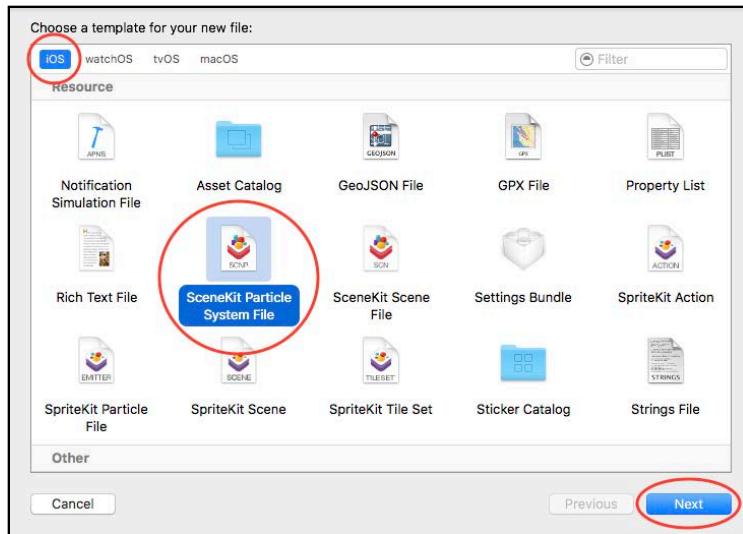
Note: You can find the starter project for this chapter under the **projects/starter/GeometryFighter** folder, or carry on with the completed project from the last chapter.

Creating a trail particle system

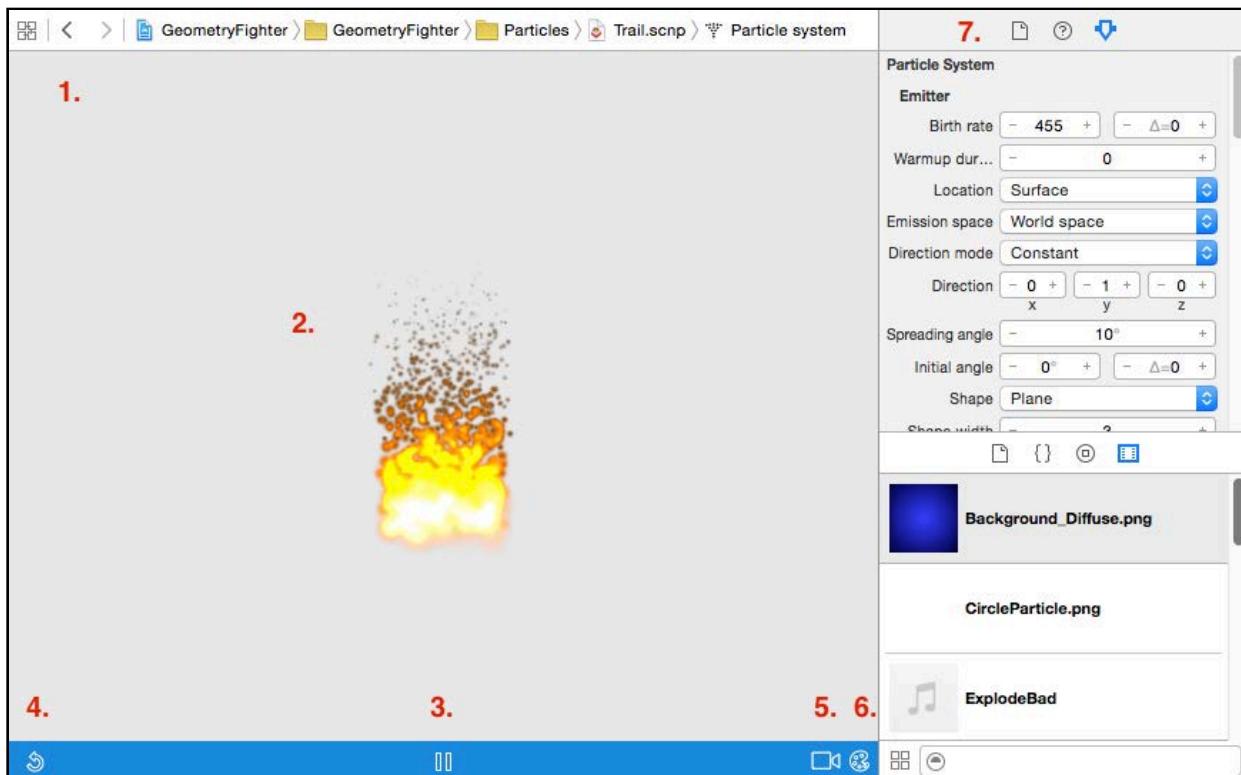
Before you add a particle system to your game world, you'll need a group to house this particle system to keep your project organized. Right-click on the **GeometryFighter** group and select **New Group**, like so:



Name this new group **Particles**. Right-click on the group and select **New File**. Select the **iOS/Resource/SceneKit Particle System** template and click **Next** to continue:



On the next screen, select **Fire** for **Particle system template**, then click **Next**. Save the file as **Trail.scnp** and click **Create**. Once you're done, you should see the following in your scene:



Hot stuff! :] Say “hello” to Xcode’s built-in particle system editor.

Here's a quick overview of the various sections of the editor as annotated above:

1. **Center stage:** The center holds a visual representation of your particle system. You can use this to get an idea of what the end result will look like.
2. **Gesture controls:** You can use gestures to manipulate the camera view; it's similar to how you'd move the camera around in a scene.
3. **Pause/Play button:** You can pause your particle system simulation and inspect it in more detail. While paused, the pause button changes to a play button which you can use to resume the simulation.
4. **Restart button:** This lets you restart your particle simulation from the beginning.
5. **Camera reset button:** Use this to reset your camera view to its default position.
6. **Color button:** This lets you set an appropriate background color for your editor; for example, it's easier to see snowflakes against a black background.
7. **Particle system properties:** Selecting the Attributes Inspector reveals a host of properties which you'll learn about in the next section.

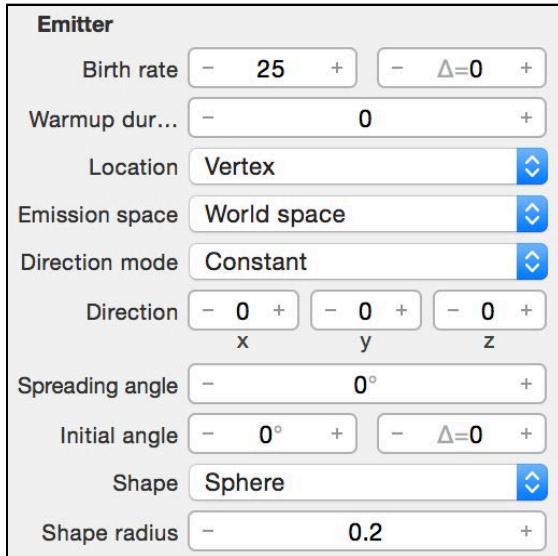
Configuring the trail particle system

In this section, you'll take an in-depth look at the particle system attributes on the right-hand side of the editor. As you go through each section, copy the values of each setting in the screenshots into your own particle system.

Keep an eye on the particle system editor as you change each attribute; you'll see how each parameter affects the behavior of the particle system. Later on, you'll use this particle effect in your game to create a trail of particles falling from your spawned objects.

Emitter attributes

The particle emitter is the origin from where all particles spawn. Here are the emitter attributes:



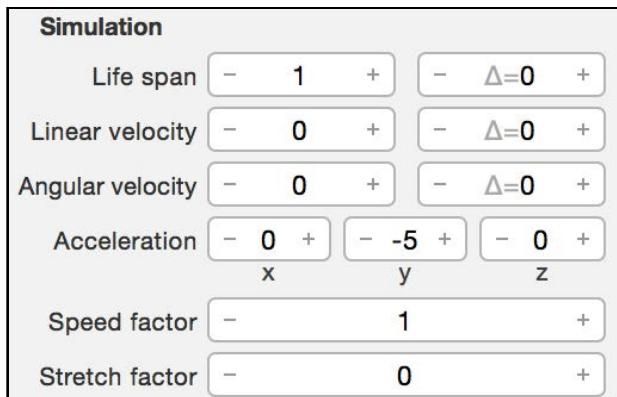
- **Birth rate:** Controls the emission rate of particles. Set this to **25**, instructing the particle engine to spawn new particles at a rate of 25 particles per second.
- **Warmup duration:** The amount of seconds the simulation runs before it renders particles. This can be used to display a screen full of particles at the start, instead of waiting for the particles to fill the screen. Set this to **0** so that simulation can be viewed from the very beginning.
- **Location:** The location, relative to the shape, where the emitter spawns its particles. Set this to **Vertex**, which means the particles will use the geometry vertices as spawning locations.
- **Emission space:** The space where emitted particles will reside. Set this to **World Space** so that the emitted particles are emitted into the world space, and not the local space of the object node itself.
- **Direction mode:** Controls how spawned particles travel; you can move them all in a constant direction, have them travel radially outwards from the surface of the shape or simply move them in random directions. Set it to **Constant**, keeping all emitted particles moving in a constant direction.
- **Direction:** Specifies an initial directional vector to use when **direction mode** is constant. Set this vector to **(x: 0, y: 0, z:0)**, setting the direction to nothing.
- **Spreading angle:** Randomizes the emitting angle of spawned particles. Set this to **0°**, thus emitting particles exactly in the previously set direction.
- **Initial angle:** The initial angle at which to emit particles. Set this to **0°** as this does not matter with a zero direction vector.
- **Shape:** The shape from which to emit particles. Set the shape up as a **Sphere**, thus using a sphere shape as the geometry.

- **Shape radius:** The existence of this attribute depends on which shape you're using; for an spherical emitter, this determines the size of the sphere. Set this to **0.2**, which defines a sphere just large enough for what you need.

Note: Note that some of the attributes have two input areas, one of which has a Δ = symbol next to it (see Birth Rate and Initial angle). The first input area contains the base value, and the Δ = input area contains the delta value. Each time a particle is spawned, it uses the base value plus a random value in the range (-delta value, +delta value). This allows you to get some random variance for these properties.

Simulation attributes

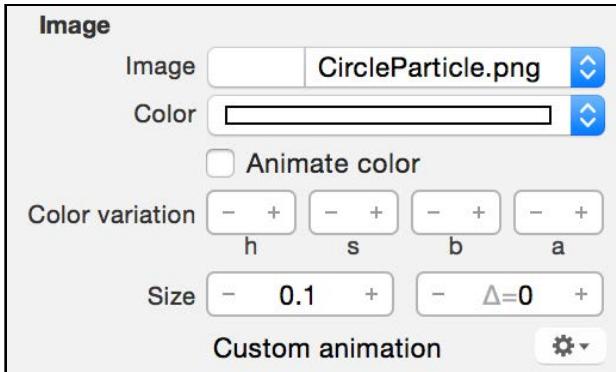
The simulation attributes manage the motion of particles over their lifetimes. This lets you manage their movement without having to use the physics engine:



- **Life span:** Specifies the lifetime of a particle in seconds. Set this to **1** so a single particle will only exist for one second.
- **Linear velocity:** Specifies the linear velocity of the emitted particles. Set this to **0** so the particles will spawn with no direction or velocity.
- **Angular velocity:** Specifies the angular velocity of the emitted particles. Set this to **0** so the particles will not spin.
- **Acceleration:** Specifies the force vector applied to the emitted particles. Set this to **(x: 0, y: -5, z: 0)** — which is a downwards vector — to simulate a soft gravity effect on the particles, once spawned.
- **Speed factor:** A multiplier that sets the speed of the particle simulation. Set this to **1** to run the simulation at a normal speed.
- **Stretch factor:** A multiplier that stretches particles in their direction of motion. Set this to **0** to not stretch the particle image.

Image attributes

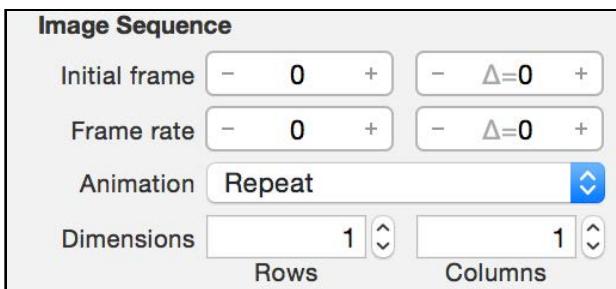
The image attributes control the visual aspects of the particles. They also govern how the appearance of those particles can change over their lifetimes:



- **Image:** Specifies an image with which each particle will be rendered. Select the **CircleParticle.png** image, giving the particle its primary shape.
- **Color:** Sets the tint of the specified image. Set the color to **White**, giving the particle system a base color of white.
- **Animate color:** Causes particles to change color over their lifetimes. **Uncheck** this, because the particle color is not going to change at all.
- **Color variation:** Adds a bit of randomness to the particle color. You can set this to **(h: 0, s: 0, b: 0, a: 0)** because the particle color will not vary.
- **Size:** Specifies the size of the particles. Set this to **0.1** so the emitted particles are small in size.

Image sequence attributes

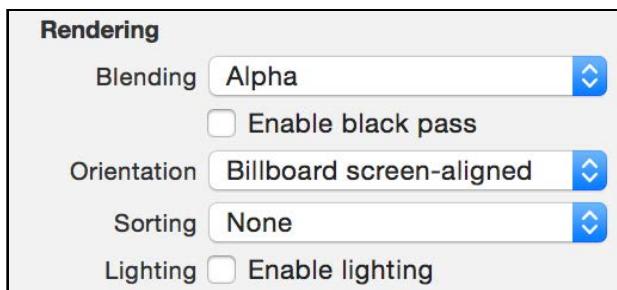
To create an animated image for your particles, you arrange each frame of the animation into a grid on a single image (like a sprite sheet in a game). Then you simply use that grid image as the image for your particle emitter. The image sequence attributes let you control the basic animation properties of the particle:



- **Initial frame:** Sets the first zero-based frame of the animation sequence. The zeroth frame corresponds to the top left image in the grid. You're using a single frame image, so set this to **0**.
- **Frame rate:** Controls the rate of the animation in frames per second. Set this to **0** as this only applies when using an image that contains multiple frames.
- **Animation:** Specifies the behavior of the animation sequence. Repeat loops the animation, Clamp only plays it once and Auto Reverse plays it from the start to the end, then back again. You can leave this on **Repeat** as this doesn't matter when using a single frame image.
- **Dimensions:** Specifies the number of rows and columns in the animation grid. Set this to **(Rows: 1, Columns: 1)** because you're using a single frame image.

Rendering attributes

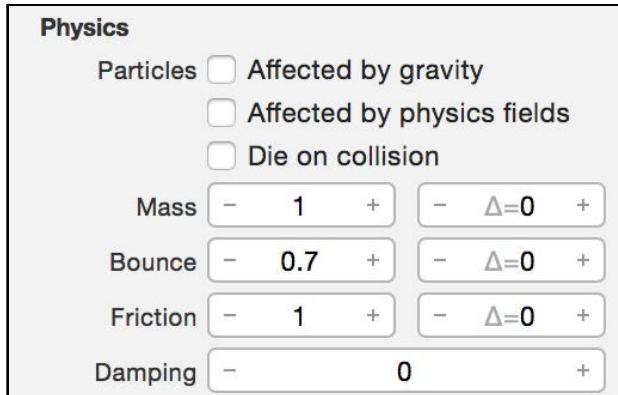
The rendering attributes define how the render phase treats the particles:



- **Blending:** Specifies the blend mode of the renderer when drawing the particles into the scene. Set this to **Alpha**, which will use the image alpha channel information for transparency.
- **Orientation:** Controls the rotation of the particles. Set this to **Billboard screen-aligned**, which will keep the flat particles facing the camera view at all times so you won't notice that the particles are indeed flat images.
- **Sorting:** Sets the rendering order of the particles. This property works in conjunction with the blend mode and affects how the blending is applied. Set this to **None** so the particle system will not make use of sorting.
- **Lighting:** Controls whether SceneKit applies lighting to the particles. **Uncheck** this so the particle system ignores any lights in the scene.

Physics attributes

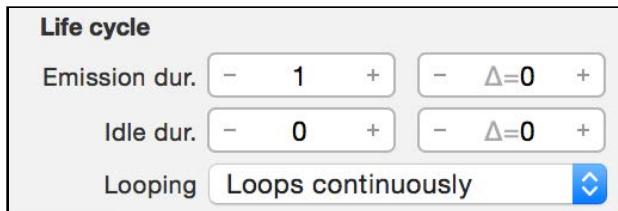
The physics attributes let you specify how particles behave in the physics simulation:



- **Affected by gravity:** Causes the scene's gravity to affect the particles. **Uncheck** this as you don't want the particle system to participate in the physics simulation.
- **Affected by physics fields:** Causes physics fields within the scene to affect the particles. **Uncheck** this as you don't want physics fields to have an effect on the particles.
- **Die on Collision:** Lets physics bodies in your scene collide and destroy the particles. **Uncheck** this as you don't want to remove particles when they collide with node objects in the scene.
- **Physics Properties:** Basic physics properties that control the physics behaviour of the particles during the physics simulation. You can leave all these at their **default values** since the particle system will not make use of this.

Life cycle attributes

The life cycle attributes let you control the overall life cycle of your particle system:

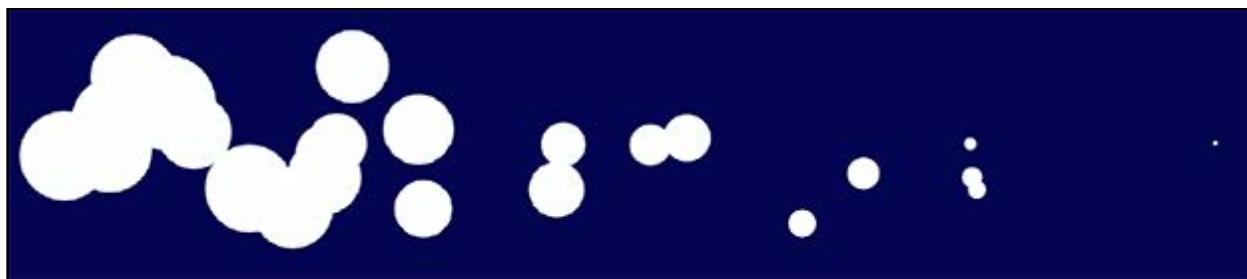


- **Emission duration:** Controls the length of time the emitter will emit new particles. Set this to **1**, which will activate the particle emitter for a total length of 1 second.

- **Idle duration:** Looping particle systems emit particles for the specified emission duration, then become idle for the specified idle duration, after which the cycle repeats. Set this to **0** so the particle system will only emit once.
- **Looping:** Specifies whether the particle system emits particles once, as in an explosion, or continuously, like a volcano. Set this to **Loops continuously** so the emitter emits for as long as it can before it's removed from the scene again.

Phew! There are a *lot* of attributes to consider for a single particle system, but this gives you a lot of control to get the exact special effect you're looking for.

If you diligently copied over the values from the screenshots to your particle system, you will have a system that represents the following effect:



If yours doesn't look like this, try rotating the camera. It might also help to change the background color to a dark blue like you see here to make the particle system easier to see.

It's finally time to add the cool particle effect to your game. Add the following to the **GameViewController.swift** class:

```
// 1
func createTrail(color: UIColor, geometry: SCNGeometry) ->
    SCNParticleSystem {
    // 2
    let trail = SCNParticleSystem(named: "Trail.scnp", inDirectory: nil)!
    // 3
    trail.particleColor = color
    // 4
    trail.emitterShape = geometry
    // 5
    return trail
}
```

Here's what's going on above:

1. This defines `createTrail(_ : geometry:)` which takes in `color` and `geometry` parameters to set up the particle system.
2. This loads the particle system from the file you created earlier.
3. Here, you modify the particle's tint color based on the parameter passed in.
4. This uses the `geometry` parameter to specify the emitter's shape.

5. Finally, this returns the newly created particle system.

This method helps you create instances of `SCNParticleSystem`, but you still need to add the particle systems to your spawned shape objects.

Note that `createTrail(_: geometry:)` takes in a color parameter and uses it to tint the particles. You will set the color of the particle system to be the same as the color of the shape.

Find the line in `spawnShape()`, where you set the shape's material diffuse contents, and split it up so the random color is stored in a constant like so:

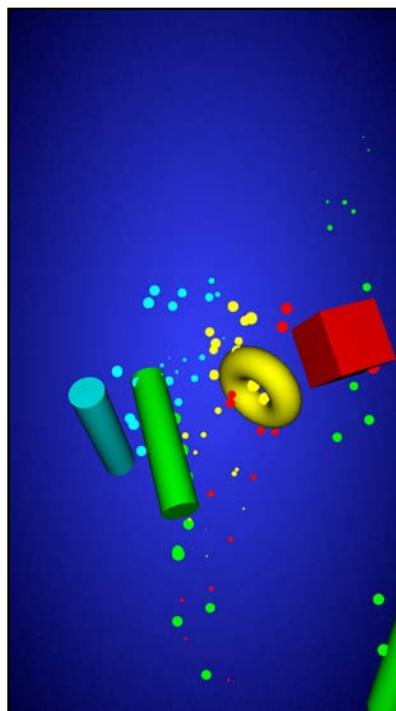
```
let color = UIColor.random()
geometry.materials.first?.diffuse.contents = color
```

Next, add the following lines further down in `spawnShape()`, just after you apply a force to the physics body of `geometryNode`:

```
let trailEmitter = createTrail(color: color, geometry: geometry)
geometryNode.addParticleSystem(trailEmitter)
```

This uses `createTrail(_: geometry:)` to create a particle system and attach it to `geometryNode`.

Build and run; take a look at your hard work in action!



Woot! :] It looks great — but what would *really* make this shine is a heads-up display.

Heads-up displays

In this short section, you'll use the *Game Utils* to quickly add a little heads-up display to show your player's remaining lives, best score and current score. The code behind the scenes uses a SpriteKit label and uses the output of the label as a texture for a plane. This is a powerful technique!

Add the following new property to **GameViewController.swift**, right below `spawnTime`:

```
var game = GameHelper.sharedInstance
```

This lets you quickly access the `GameHelper` shared instance, which contains a set of methods to do the heavy lifting for you.

Add the following method to the bottom of `GameViewController`, below `createTrail()`:

```
func setupHUD() {
    game.hudNode.position = SCNVector3(x: 0.0, y: 10.0, z: 0.0)
    scnScene.rootNode.addChildNode(game.hudNode)
}
```

Here, you make use of `game.hudNode` from the helper library. You set the HUD node's position and add it to the scene.

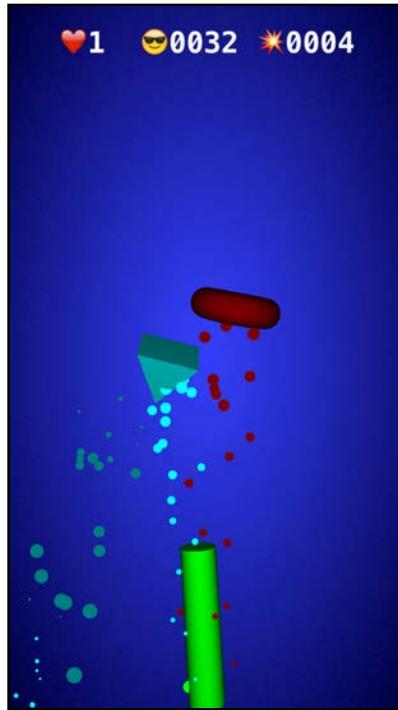
Next, you need to call `setupHUD()` from somewhere. Add the following line to the bottom of `viewDidLoad()`:

```
setupHUD()
```

Now that you have a heads-up display, you need to keep it up to date. Add the following call to `game.updateHUD()` to the bottom of `renderer(_:_:updateAtTime:)`

```
game.updateHUD()
```

Build and run; you'll see your display at the top of the screen as shown below:



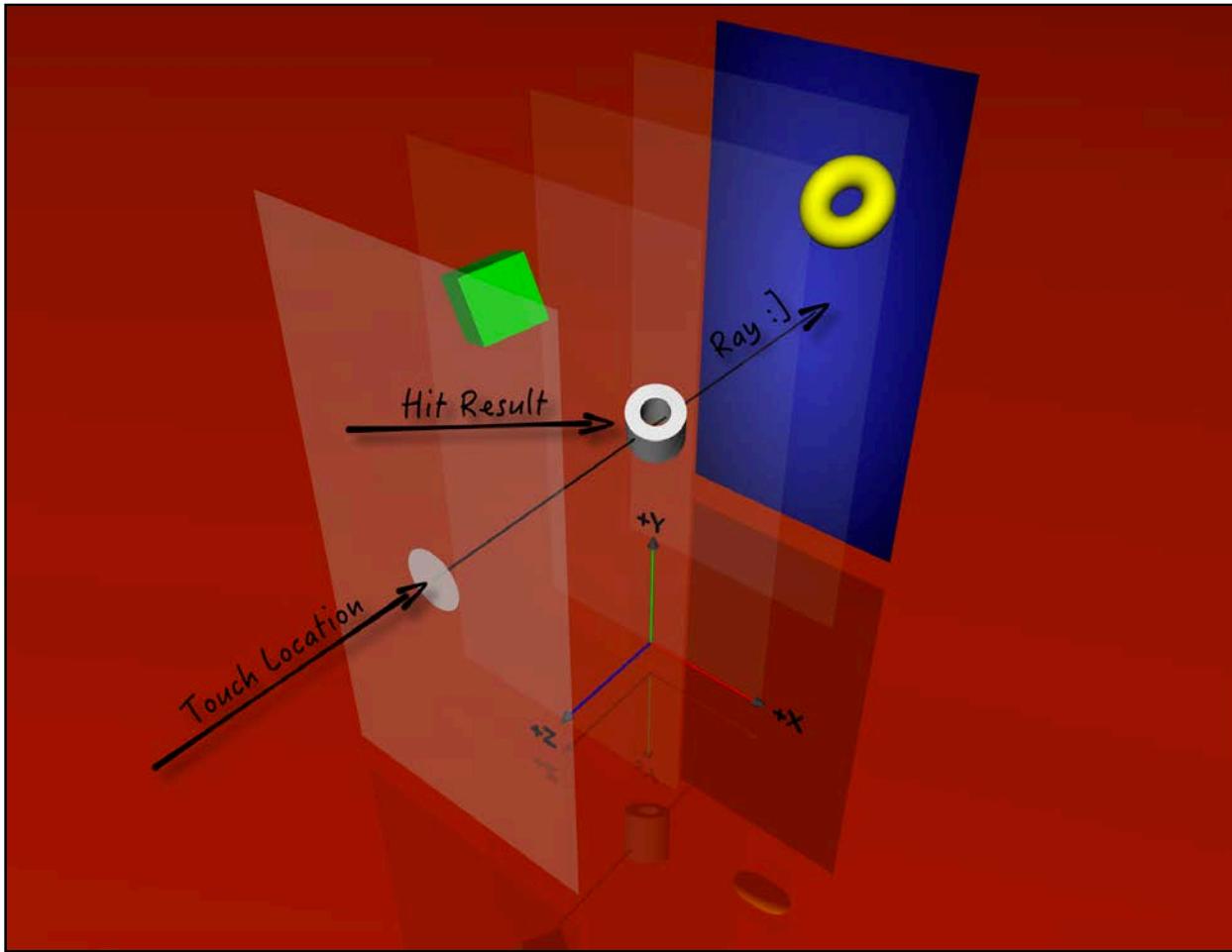
Your game now has a nifty little HUD with a life counter, the high score and the current score.

Okay, the heads-up display is nice, but it's high time to add some interaction to your game.

Touch handling

As is usually the case, enabling touch in your app isn't as straightforward as one would hope.

The first step is to understand how touch handling works in 3D. The image below shows a touch point in a side view of your scene and how SceneKit translates that touch point into your 3D scene to determine which object you're touching:



So what steps do you take to handle the user's touch event?

1. **Get touch location:** First, you need to get the location of the user's touch on the screen.
2. **Convert to view coordinates:** After that, you need to translate that touch location to a location relative to the SCNView instance that's presenting the scene.
3. **Fire a ray for a hit test:** Once you've established a touch location relative to the view, SceneKit can perform a hit test for you by firing off a ray (no, not *that* Ray! :]) into your scene and returning a list of objects that intersect with the ray.

Naming nodes

Before you can activate the touch ray of death, you need a way to identify each spawned object. The simplest approach is to give them names.

Add the following to `spawnShape()`, right after you add the particle system to `geometryNode`:

```
if color == UIColor.black {  
    geometryNode.name = "BAD"  
} else {  
    geometryNode.name = "GOOD"  
}
```

True to the spirit of the black-hatted villains of old Western movies, you assign the moniker "BAD" to black-colored objects and "GOOD" to all others.

Adding touch handling

Next, you need to write a method that you'll later call when you detect the user has tapped a particular node.

Add the following method to the bottom of `GameViewController`, below `setupHUD()`:

```
func handleTouchFor(node: SCNNode) {  
    if node.name == "GOOD" {  
        game.score += 1  
        node.removeFromParentNode()  
    } else if node.name == "BAD" {  
        game.lives -= 1  
        node.removeFromParentNode()  
    }  
}
```

This method checks the moniker of the touched node; good nodes increase the score and bad (black) nodes reduce the number of lives by one. In either case, you remove the node from the screen as it's destroyed.

Using the touch handler

To capture the user's touches, you'll use `touchesBegan(_:_)`, which is called every time the player touches the screen.

To implement your own version, add the following to `GameViewController`, right below `handleTouchFor(_:_)`:

```
override func touchesBegan(_ touches: Set<UITouch>, with event: UIEvent?) {  
    // 1  
    let touch = touches.first!  
    // 2  
    let location = touch.location(in: scnView)  
    // 3  
    let hitResults = scnView.hitTest(location, options: nil)  
    // 4  
    if let result = hitResults.first {  
        // 5  
        handleTouchFor(node: result.node)  
    }  
}
```

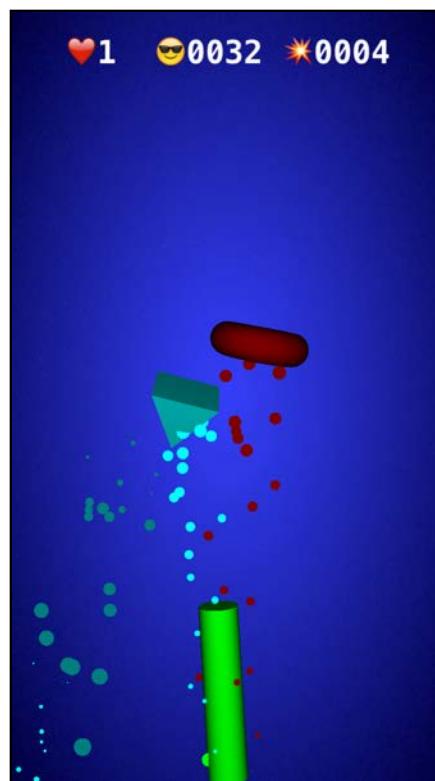
Taking each numbered comment in turn:

1. Grab the first available touch. There can be more than one if the player uses multiple fingers.
2. Translate the touch location to a location relative to the coordinates of scnView.
3. hitTest(_: options:) gives you an array of SCNHitTestResult objects that represent any intersections of the ray starting from the spot inside the view the user touched, and going away from the camera.
4. Check the first result from the hit test.
5. Finally, you pass the first result node to your touch handler, which will either increase your score — or cost you a life!

One final step. You don't need the camera control anymore so change the line in setupView() as follows:

```
scnView.allowsCameraControl = false
```

Build and run; get ready to unleash your deadly finger of annihilation! :]



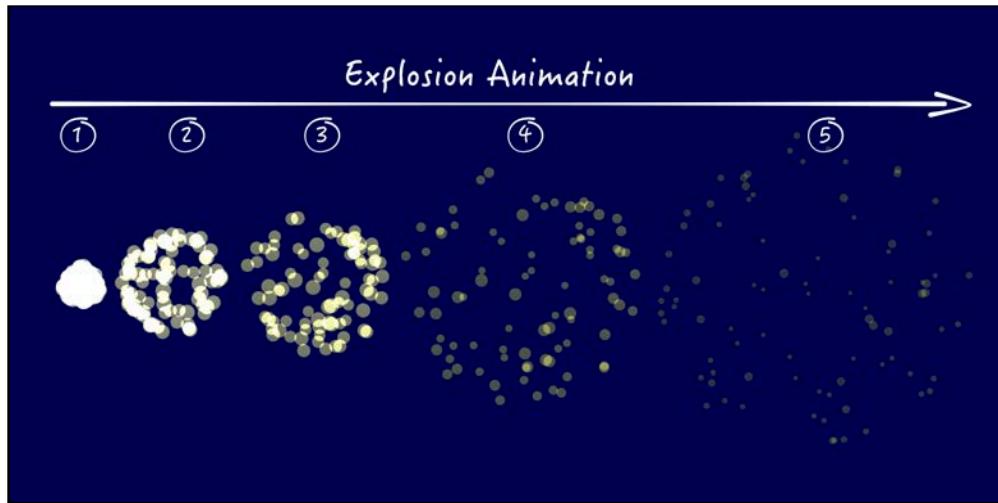
Tap on the spawned objects and make them disintegrate into thin air. Whoo-hoo! :]

Challenge

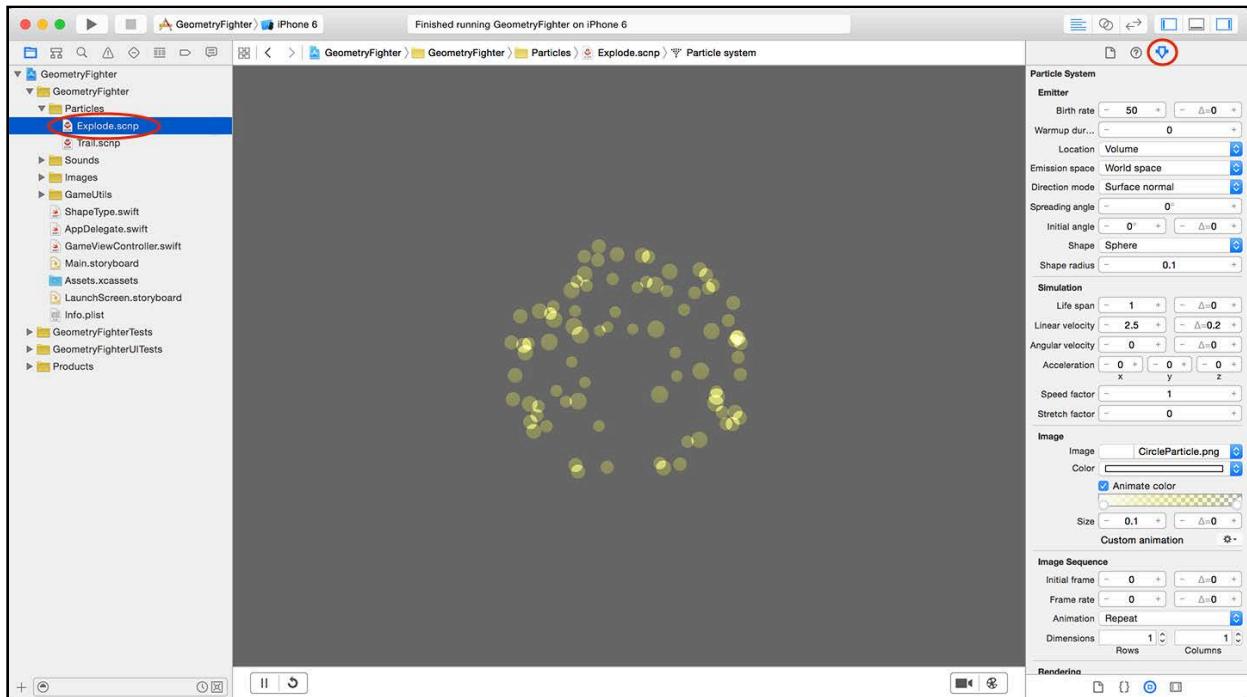
Time to up the cool factor — and what's cooler than *explosions*? Absolutely *nothing*, right?

That brings you to the challenge of this chapter, and that is to create another particle system and name it **Explode.scnp**. See if you can figure out what attributes to modify to make those particles explode.

The effect should look something similar to this:



You can use the following image as a starting point for your particle system:



Note: You can find the solution under the **projects/challenge/GeometryFighter** folder. Open up **Explode.scnp** under the **Particles** group to get a closer look.

Shaping particle explosions

Now that you've created the explosion particle system, you need to add some code to make those nodes explode. You're going to use some special properties to make the explosion take the same shape as whatever node you touch.

Add the following to the bottom of GameViewController, below touchesBegan(_:withEvent):

```
// 1
func createExplosion(geometry: SCNGeometry, position: SCNVector3,
    rotation: SCNVector4) {
// 2
    let explosion =
        SCNParticleSystem(named: "Explode.scnp", inDirectory:
    nil)!
    explosion.emitterShape = geometry
    explosion.birthLocation = .surface
// 3
    let rotationMatrix =
        SCNMatrix4MakeRotation(rotation.w, rotation.x,
            rotation.y, rotation.z)
    let translationMatrix =
        SCNMatrix4MakeTranslation(position.x, position.y,
            position.z)
    let transformMatrix =
        SCNMatrix4Mult(rotationMatrix, translationMatrix)
// 4
    scnScene.addParticleSystem(explosion, transform: transformMatrix)
}
```

Here's the play-by-play for the above code:

1. `createExplosion(_: position: rotation:)` takes three parameters: `geometry` defines the shape of the particle effect, while `position` and `rotation` help place the explosion into the scene.
2. This loads **Explode.scnp** and uses it to create an emitter. The emitter uses `geometry` as `emitterShape` so the particles will emit from the surface of the shape.
3. Enter the Matrix! :] Don't be scared by these three lines; they simply provide a combined rotation and position (or *translation*) transformation matrix to `addParticleSystem(_: withTransform:)`.

4. Finally, you call `addParticleSystem(_: withTransform)` on `scnScene` to add the explosion to the scene.

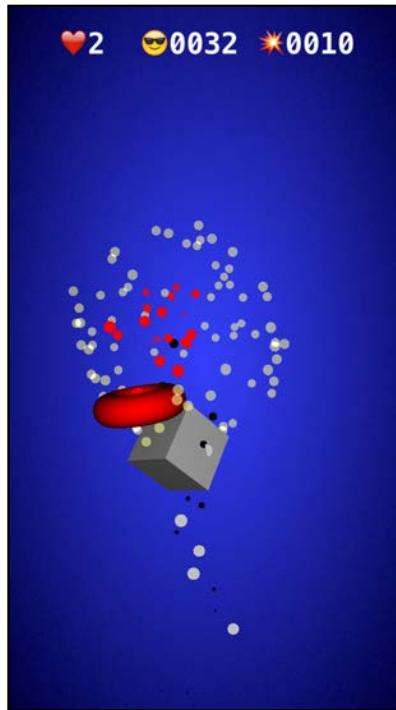
You're so close to replicating those great Hollywood explosions! Add the following line twice inside `handleTouchFor(_:)` — once to the "good" if block and once to the "bad" else block, right before you remove node from the parent:

```
createExplosion(geometry: node.geometry!,  
    position: node.presentation.position,  
    rotation: node.presentation.rotation)
```

This uses the `presentation` property to retrieve the position and rotation parameters of `node`. You then call `createExplosion(_: position: rotation:)` with those parameters.

Note: You're using `presentation` because the physics simulation is currently moving the node.

Build and run; tap away and make those nodes explode!



Note: You can find the project for this challenge under the **projects/challenge/GeometryFighter** folder.

Adding juice

To push your game to that next level, you absolutely have to add something known as *juice*. Juice will give your game that little something special, just to make it stand out above the rest.

Here are a few ideas that will definitely juice things up:

- **Game state management:** With basic game state management you'll be able to control certain game mechanics based on a game state like TapToPlay, Playing or GameOver.
- **Splash screens:** Use pretty splash screens. They provide the player with visual clues of the current game state.
- **Sound effects:** Add cool sound effects to provide the player with crucial audio feedback of good and bad interaction with the game elements.
- **Camera shakes:** Really big explosions produce really big shockwaves. Add a shaking camera effect to give your game a little something extra.

Note: Now for a special bonus! :] There's a ready made project waiting for you under the **projects/juiced/GeometryFighter** folder. Open it and try it out. Feel free to explore the project; discover how adding just a few lines of code can take your game to the next level.

Where to go from here?

You've reached the end of the first section of this book — and you have a great SceneKit game to boot! Feel free to do your happy dance! :]

In this chapter you learned about the following:

- **Particle systems:** How to add particle effects to your game using particle systems.
- **Particle system editor:** How to navigate the built-in particle system editor and how to preview your effects.
- **Particle system attributes:** How to work with the numerous attributes that define the workings of a particle system.
- **3D touch handling:** How to manage touch events in 3D and how to use `hitTest(_: options:)` to determine which nodes were touched inside your scene.

Congratulations on completing your first SceneKit game — now get ready to level-up your skills with something completely new!

Section II: The SceneKit Editor

Xcode includes a variety of standard built-in tools, and in this section, you'll take an in-depth look at them. These tools will make building your 3D games with SceneKit so much easier, faster and even more fun.

Throughout this section, you'll be making a game named Breaker, which is based on *Breakout*, but it adds a nice new 3D look and feel. Keep your paddle and ball close by, so you can go bust up some bricks! :]



[Chapter 6: SceneKit Editor](#)

[Chapter 7: Cameras](#)

[Chapter 8: Lights](#)

[Chapter 9: Geometric Shapes](#)

[Chapter 10: Basic Collision Detection](#)

6 Chapter 6: SceneKit Editor

Chris Language

Getting started

With Xcode's latest release, Apple has proven that it considers game development to be a worthy cause. The company exerted a monumental effort to create tools that help game developers build cooler games.

Specifically, Apple created several new, essential tools for SceneKit game development in Xcode.

Xcode goes further than just editing and compiling code, especially for games. With the release of Xcode 6, Apple introduced a built-in scene editor for SpriteKit. Xcode 7 introduced a built-in scene editor for SceneKit too.

Similar to how the SpriteKit scene editor helps you design 2D SpriteKit games visually, the SceneKit scene editor helps you work with 3D objects and design 3D SceneKit games.

The purpose of both editors is to provide you with a what-you-see-is-what-you-get (WYSIWYG) environment so you can visualize the result. All this without stepping foot outside Xcode or even building and running your game — how cool is that?

But wait, there's more! These scene editors are taking it a step further by allowing you to play the scene's animations and physics simulation within Xcode, giving you an even more accurate depiction of the end result.

Although Xcode is mighty and powerful, it can't prevent a zombie apocalypse, nor can it prevent you from ever having to code again.

You'll still need to add some code behind the scenes, but fear not, you'll learn all about that and more right here, right now.

SceneKit game project

It's time to kick-off your next game by creating a new project for it. You'll use the same techniques as the previous section and make use of Xcode's built-in **Game Application Template**.

Note: This is an optional section that shows you how to create a bare-bones project from scratch. It's basically a review of the material you've already covered in Section I. If you'd like a refresher, keep reading, but if you'd like to get straight to the fun new stuff, skip ahead to the next section, "SceneKit editor". A starter project waits for you there.

Also note that this chapter won't go into the same gory level of detail as previous chapters, so refer to Section I if you're struggling with the specifics of starting a new project.

Creating the SceneKit game project

Open Xcode, create a new project and select the **iOS/Application/Game** template.

Enter **Breaker** for the project name, and make sure you're using **Swift** for Language, **SceneKit** for Game Technology, **Universal** for Devices and leave both test options **unchecked**.

After creating the project, delete the existing **art.scnassets** folder and replace the contents of **GameViewController.swift** with the following:

```
import UIKit
import SceneKit

class GameViewController: UIViewController {

    var scnView: SCNView!

    override func viewDidLoad() {
        super.viewDidLoad()

        // 1
        setupScene()
        setupNodes()
        setupSounds()
    }

    // 2
    func setupScene() {
        scnView = self.view as! SCNView
        scnView.delegate = self
    }

    func setupNodes() {
```

```
}

func setupSounds() {
}

override var shouldAutorotate: Bool { return true }

override var prefersStatusBarHidden: Bool { return true }
}

// 3
extension GameViewController: SCNSceneRendererDelegate {
    func renderer(_ renderer: SCNSceneRenderer,
                  updateAtTime time: TimeInterval) {
    }
}
```

This code snippet should look familiar because it's a barebones version of `GameViewController` from Section I. There are a few things to note:

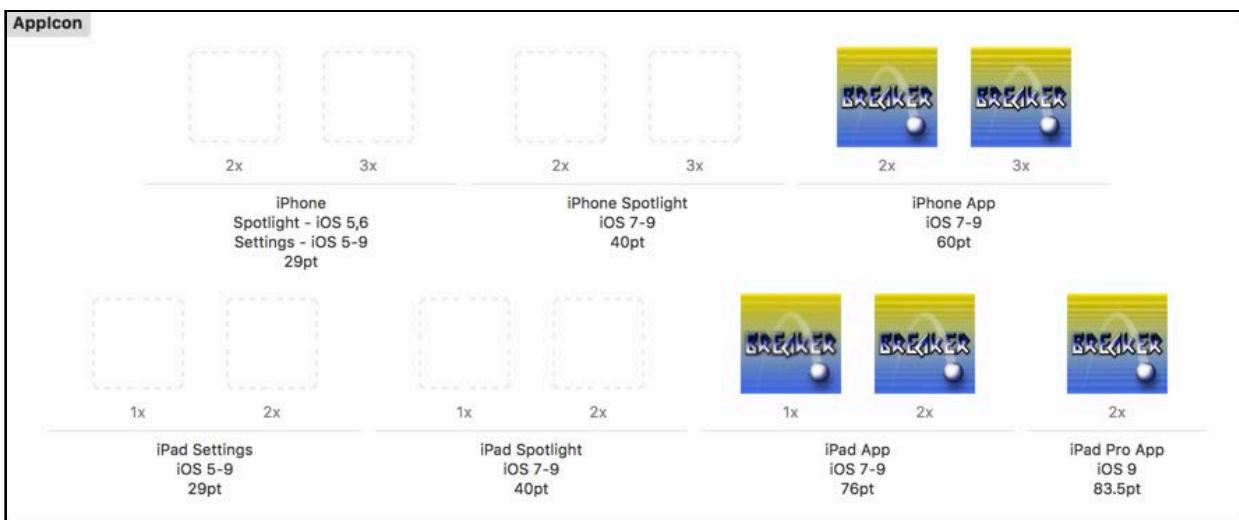
1. You call a few stub methods inside `viewDidLoad()`. A bit later, you'll add code to these methods to set up your game.
2. The scene setup consists of casting `self.view` as a `SCNView` and storing it for convenient access, as well as setting up `self` to be the render loop delegate.
3. As the delegate for the scene, `GameViewController` conforms to the `SCNSceneRendererDelegate` protocol, and there's a stub for `renderer(_:updateAtTime:)` that's called once for every frame update.

Adding app icons

App icons are a player's first impression of a game, so it's important to make something very pretty, shiny and even flashy. You'll create nothing less for your app's game icon.

Take a look under the **resources/AppIcon** folder and note the various sizes of app icons in there. To add these to your project, open up **Assets.xcassets** and select **AppIcon**. Drag and drop the icons from the resources folder to the appropriate spots.

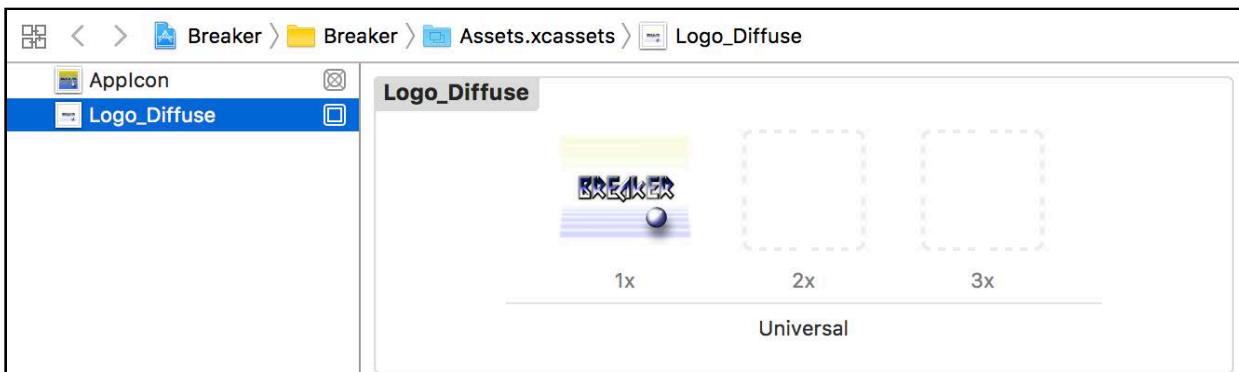
Your **AppIcon** pane should look like this when you're done:



Adding the launch screen image

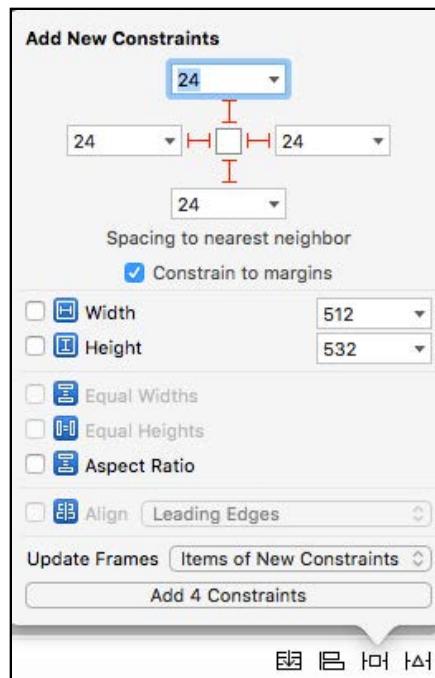
Once your app icon is in place, it's time to configure your launch screen.

Select **Assets.xcassets** first, then drag and drop **resources/Logo_Diffuse.png** into it. You should end up with this:

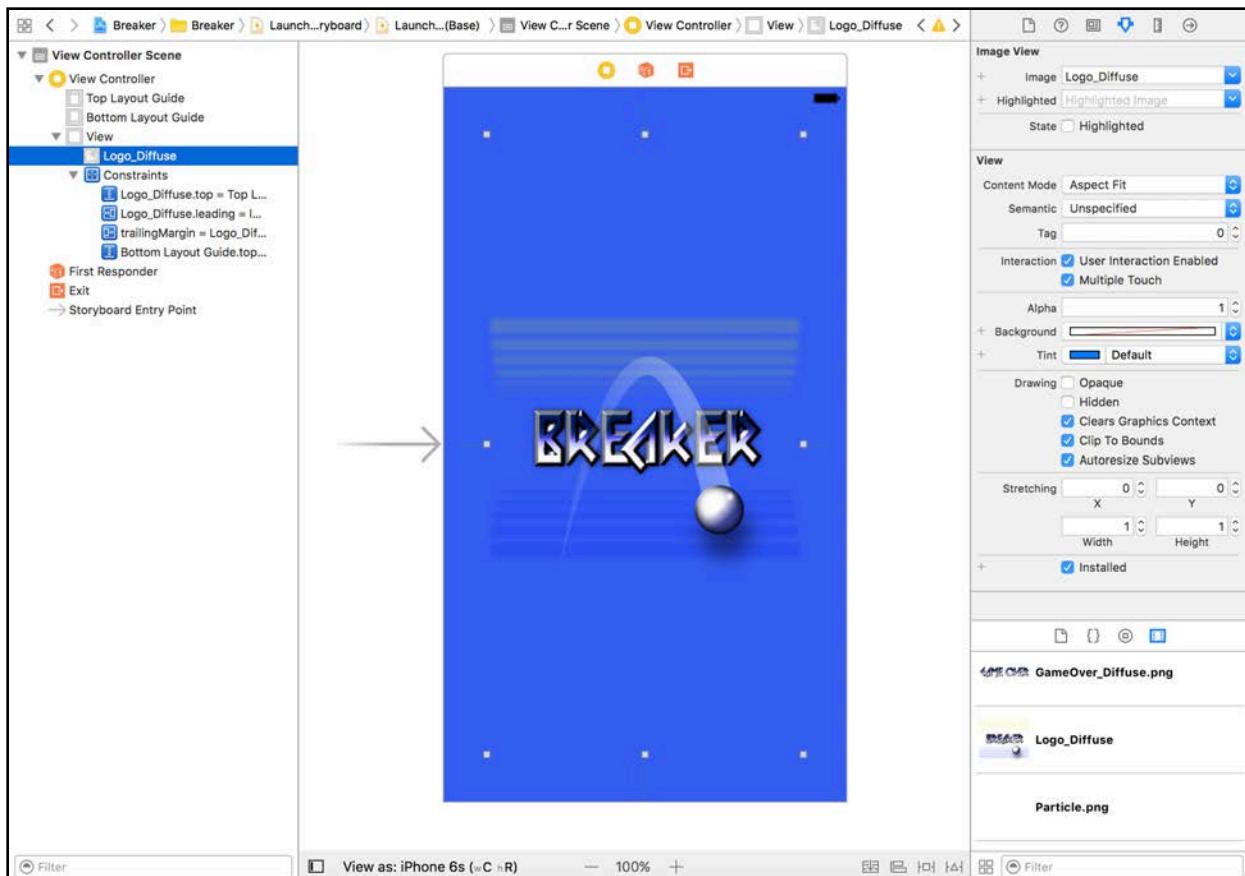


Open **LaunchScreen.storyboard** and change the view's background color to dark blue. Next, find **Logo_Diffuse** under the **Media Library** at the bottom-right and drag it onto your launch screen.

Change the image view's **Content Mode** to **Aspect Fit**, and make sure to add constraints to the image so it looks correct on all screen sizes:



That's it, you're done setting up the launch screen! It should look something like this:



Adding the asset catalog

You need to introduce some “wow factor” to your game — the graphics and sound assets. You’ll find these resources inside the **resources/Breaker.scnassets** asset catalog, so drag and drop the entire folder into your game project. Make sure to select **Copy items if needed**, **Create groups** and **Breaker** target.

Once done, the folder will be part of your project. There are subfolders within **Breaker.scnassets**, namely, **Sounds** and **Textures** that hold the sound and graphic assets.

Adding the game utilities

You’ll be making use of the same game utilities as before. This time around, however, you’ll use some additional methods and extensions, so the 3D math takes a little less of your precious life force.

Drag and drop the **resources/GameUtils** folder into your project under the **Breaker** group.

Note: You’ll actually import the entire folder into your project as a group folder named **GameUtils**. It’s advisable to take a closer look at the files inside this folder, but there’s no need to fry your brain in an attempt to decode all the math. At this point, it’s more important to know how to *use* it than understand *how* it works! :]

Adding the game helper functions

With the game utilities inside your project, you can start taking advantage of them by adding a GameHelper to the game. It’s the same helper class you used in Section I, and its purpose is to do the heavy lifting so you can focus on learning the concepts laid out in this chapter.

Open up **GameViewController.swift** and add the following property to GameViewController, right below scnView:

```
var game = GameHelper.sharedInstance
```

This gets a shared instance of GameHelper and stores it in game for later. Build and run.



Although the game starts up in total darkness, it does sport a flashy icon and launch screen at startup. More importantly, it has a solid foundation upon which you can build your masterpiece.

SceneKit editor

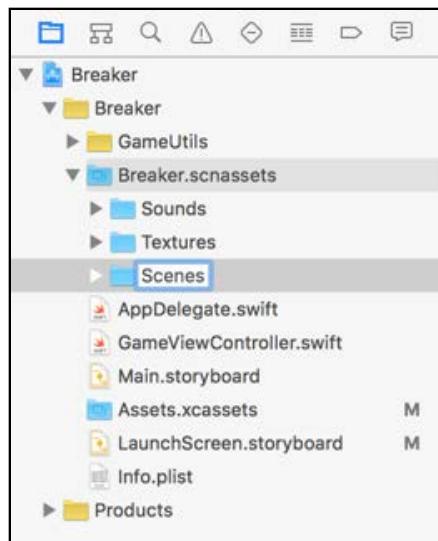
Note: If you skipped the previous section, pick things up with the starter project designed for this point under **projects/starter/Breaker**.

It's almost time to delve into the SceneKit editor and explore its myriad of features, but first, you need a new scene in the game, so you have something to play with.

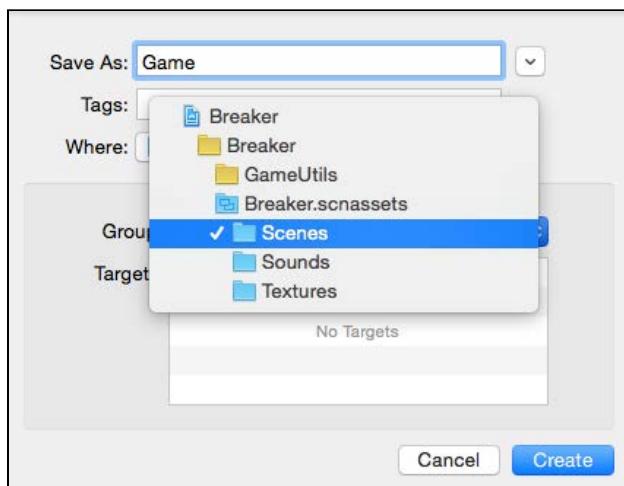
This time, instead of creating a scene via code, you'll be making one inside a scene file.

Adding a SceneKit scene

Right-click **Breaker.scnassets**, and then create a **New Folder** named **Scenes** for all your scenes.

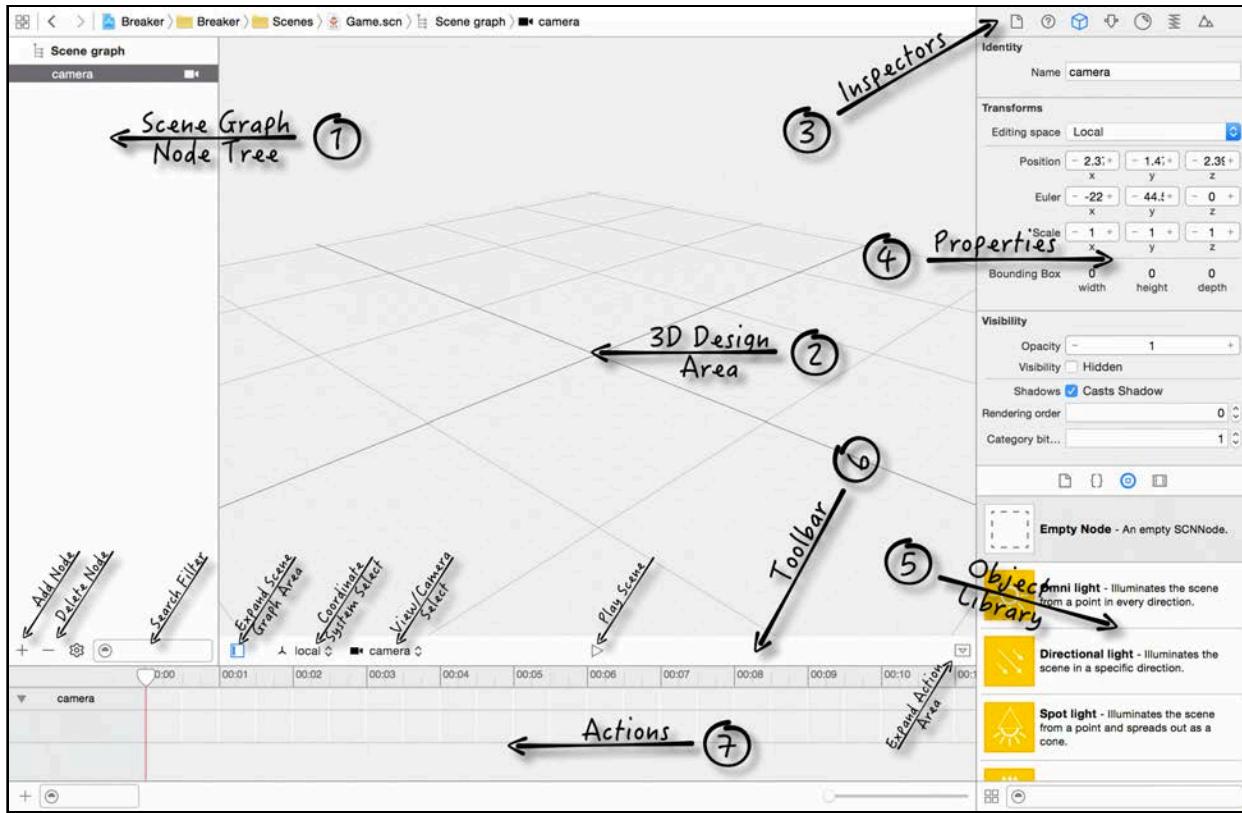


With the **Breaker** group selected, create a new file and select the **iOS/Resource/SceneKit Scene** template. Name the file **Game.scn**, and where it says **Group**, make sure to navigate to the new **Scenes** folder inside your **Breaker.scnassets** asset catalog.



Note: There is good reason for selecting the **Breaker** group then manually changing the **Group** option: If you had created a new file with an asset catalog selected, Xcode would have created a brand new file and never brought up the file creation wizard. Try it and see for yourself!

Select **Game.scn** and you should now see the SceneKit editor in its full glory.



Learning your way around the SceneKit editor

This might look like a diagram for a football play, but it's actually your key to understanding SceneKit. In fact, each numbered arrow points to an essential element, detailed below:

- Scene graph:** This tree structure comprises your scene graph; every element in the scene shows here. You can drag and drop elements around within the tree hierarchy in order to control parent-child relationships.
- Design area:** This is the visual representation of your scene. You'll be able to pan, rotate and zoom around in this view just like a typical first-person shooter. You'll also be able to drag and drop primitive nodes from the Object Library into the scene, where you can copy, move and rotate them.
- Inspectors:** These inspectors are context-dependent, and their contents will change based on the actively selected node in your scene graph. You should already be familiar with the File and Quick Help Inspectors, but there are five new inspectors to take note of here:
 - Node Inspector:** These properties refer to the base SCNNode object properties, so every node in your scene will have the same set of properties found in this inspector.

- **Attributes Inspector:** These properties are from the type of node object currently selected. So if you select a *Box*, for example, you'll be able to set its width and height; if you pick a *Sphere*, you'll be able to set its radius.
 - **Material Inspector:** This is where you'll assign colors and textures to the nodes in the scene.
 - **Physics Inspector:** This is where you'll enable and configure physics behaviors for the nodes in the scene.
 - **Scene Inspector:** This inspector is global to all the nodes in the scene because it allows you to set a few of the scene's properties. However, you must select at least one node to gain access to these properties.
4. **Properties:** This is where you adjust the properties for the selected inspector.
 5. **Object Library:** This is where you'll find all the available SCNNode objects ranging from primitive nodes to self-defined nodes. Just drag and drop nodes directly into the design area to allow visual manipulation of the objects. Also, note that SCNAction objects are stored in this list.
 6. **Toolbar:** This contains several elements of importance. From left to right, here's a closer look at each:
 - *Add/delete node:* When you select a node in the scene graph, you can use this to add an empty child node or delete the currently selected node.
 - *Search filter:* While you're building wonderfully complex scenes, you can use this to filter the scene graph to find a specific node quickly.
 - *Expand/collapse scene graph area:* This button expands or collapses the scene graph area.
 - *Coordinate system:* This allows you to pick an active coordinate system for editing your nodes in the designer area. You can choose from local, parent, world or screen.
 - *View/camera select:* When your scene has more than one camera, you'll be able to select the active viewpoint from this drop-down list of cameras.
 - *Play/stop scene:* This starts or stops the physics and actions simulation.
 - *Expand/collapse actions:* This button expands or collapses the actions area.
 7. **Actions area:** When you add actions to your nodes, this is where you drag and drop actions from the Object Library that will affect the selected node.

Navigating a basic scene

To design your scenes properly — and the way you've envisioned them — you'll need to know the secrets of how to move around with elegance while you're viewing the scene.

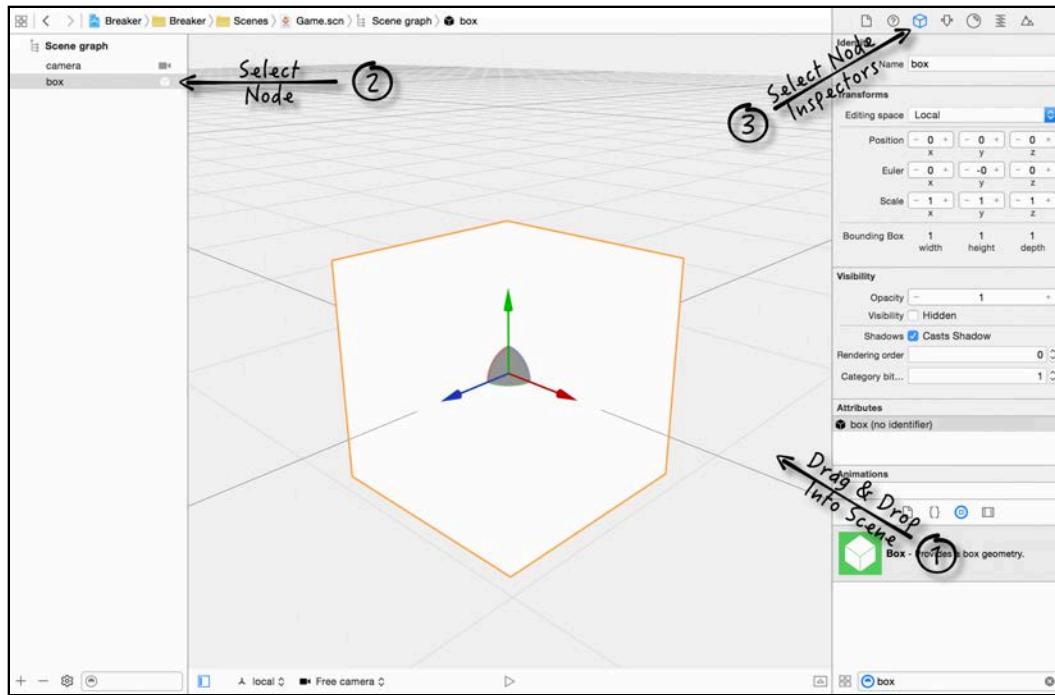
Put your mouse cursor inside the design area, and try the following gestures to navigate the active view:

- **Pan:** Roll the imaginary mouse wheel in any direction on a Magic Mouse or use a two-finger gesture on a trackpad to move your view left, right, up or down. On a regular mouse, you can press and hold Option and drag.
- **Rotate:** Click and hold the left mouse button down while moving the mouse cursor around to rotate the view.
- **Zoom:** Press and hold Option while rolling the imaginary mouse wheel up or down to zoom with a Magic Mouse. On a trackpad, you can pinch-in and pinch-out to adjust the zoom.
- **Multi-selection:** Press and hold Command then left-click and drag the mouse cursor over multiple nodes to select all of them at once.

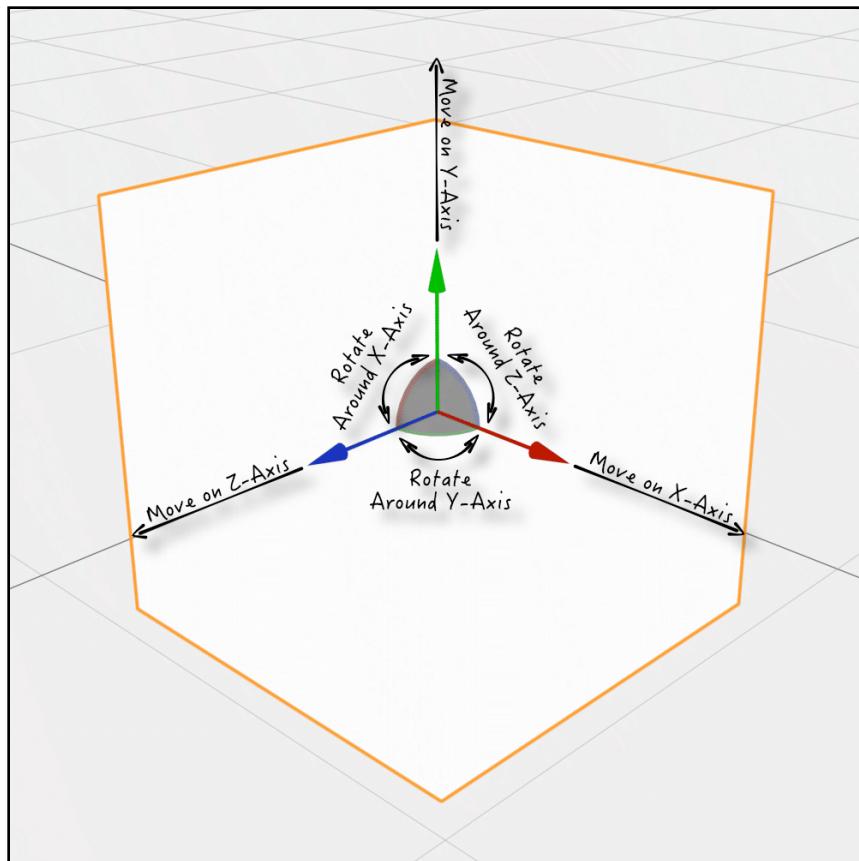
Manipulating a basic node

For the sake of having a subject to work with, first, add a basic box node into the scene.

Find the **Box** object inside the Object Library on the bottom-right. Then **drag and drop** the **Box** from the **Object Library** to anywhere in your scene. Make sure you've selected this new node in the scene graph, and then open the Node Inspector:



You've just added your first node to the scene graph using the SceneKit editor. Now for a breakdown of this node:



When you move your mouse over the colored lines, gray sectors or colored arcs, you'll notice how they light up. These guides allow for manipulation of the following node properties:

1. **Positioning:** Pull on a highlighted axis arrow to move the node on that specific axis without any effect to the other two axes' positions. By dragging the gray sectors, you'll move the node along the two axes the sector is touching.
2. **Rotation:** By pulling on the highlighted axis curve, you'll be able to rotate the node around that specific axis without an effect on the rotation of the other two axes' rotations.

There are some additional options you should note for positioning and rotating a node:

- **Position snapping:** While moving the node, press and hold Command to snap the node to the grid layout, or to a nearby surface. It allows for quick and precise node positioning.
- **Angle snapping:** While rotating the node, hold Command to snap to 45-degree angles around selected axis. It allows for quick and precise node rotation.
- **Copying:** While holding Option, you can move a node to create a shared instance of the node. This allows you to copy a node quickly. It's important to note that this creates a *shared* instance of the original node. Any changes to the node attributes will affect all shared copies. There is a button to unshare these projects inside the Attributes Inspector under the geometry sharing category should you feel the need to do that.

If you moved your box to experiment, use the Attributes Inspector to set the Position back to 0, 0, 0 before moving on.

Present a SceneKit scene

To wrap up your learnings for this chapter, all you need to do is load up the newly created scene file and present it in your view.

Load and present the scene

To present your scene, add a new property inside GameViewController right below the scnView property:

```
var scnScene: SCNScene!
```

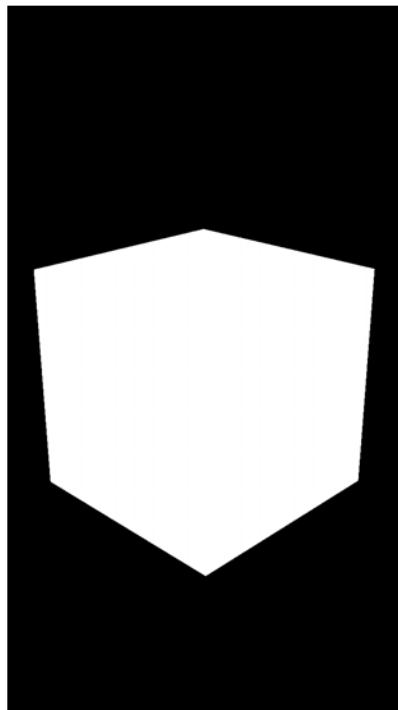
This property grants you convenient access to the game's scene.

Next, at the bottom of setupScene(), add the following code:

```
scnScene = SCNScene(named: "Breaker.scnassets/Scenes/Game scn")
scnView.scene = scnScene
```

Conveniently, SCNScene has an initializer that allows you to pass in the file name of a scene file. It's important to note that you specified the path **Breaker.scnassets/Scenes/Game scn** because it points to the scene file. Then, once the scene is created, you set scnScene as the active scene for the view.

Wow, that was easy! :] Build and run at this point and you should see your scene:



Although things are looking rather “square” at the moment, you’ve still made good progress on this game.

Soon you’ll have lights, camera *and* action but not in this chapter.

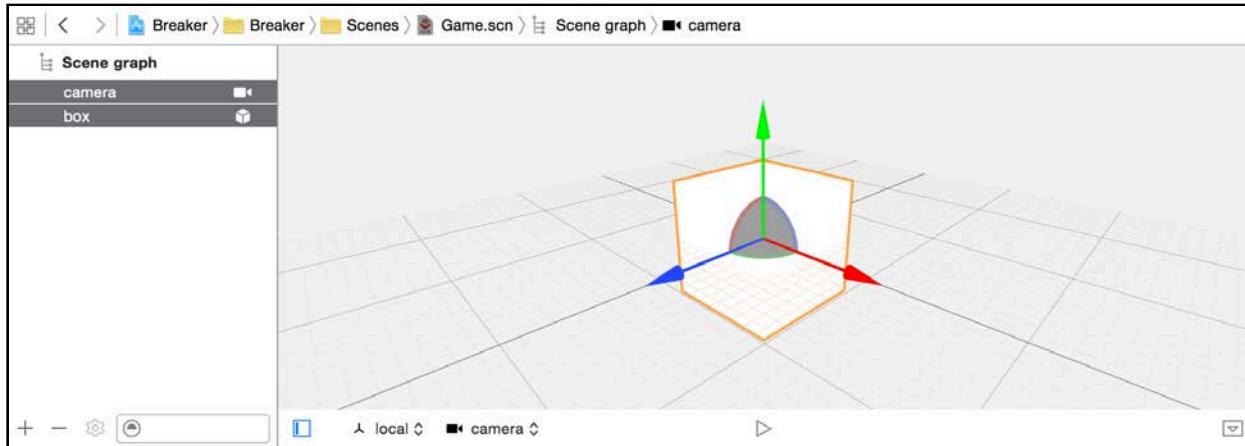
Cleaning up the scene

It’s time to close it out and clean it up before you move on to the next chapter. Simply delete all the nodes in your scene graph — including the **camera** node.

You’ll need to start from scratch in the following chapters. The nodes you added in this chapter were simply playthings used to familiarize yourself with the tools.

Deleting all the nodes

In the scene graph, press **Command-A** to select all nodes in the scene, then press the **Delete** key to kill them all.



No need for a build and run at this point, because the scene is empty and it would be an unimpressive lot of emptiness. :]

Where to go from here?

You're one step closer to mastering the concepts inherent to 3D game creation. Your fingers may not have done much during this chapter, but your brain learned quite a few important concepts that you'll need to move forward:

- **SceneKit editor:** You learned how to create a new SceneKit scene file and view it using the built-in SceneKit editor.
- **Navigation:** You learned how to pan, move and rotate around the scene designer area.
- **Adding nodes:** You learned how to add nodes to your scene from the Object Library.
- **Manipulating nodes:** You learned how to manipulate a node's position and rotation, and how to make copies of it from inside the Scene Editor.

Stay tuned for the next chapter, where you'll add the camera back into the game!

Note: You can find the final project for this chapter under the **projects/final/****Breaker** folder.

Chapter 7: Cameras

Chris Language

Getting started

In Section I, you learned about the camera and its role in the rendering pipeline where it controls settings like the visible frustum, distance and area.

Cameras, functionally-speaking, are your eyes into the game world. They serve as *the point of view*. You see what they see, but there's more to love about cameras. You're in *control* of how they perceive and project your game.

Under your guidance, the camera can see your game from every angle. Want a top-down camera to show the whole board? No problem. Want a view that shows the floor from a cat's perspective? Totally possible. Want to switch between cameras based on device orientation? You can do that — all of that.

SceneKit, as you've learned, makes you rather powerful; for instance, you can actually create as many different cameras in a scene as your heart desires. Stay tuned — that's covered in this chapter.

There is a limitation to think about. Only one camera can serve as the active view point for your scene at any given time. You don't get to play around with picture-in-picture or overlapped shots.

In light of that, know that you *can* actively pick and choose the best camera for each part of the game, just like a director switches between cameras when filming a live show.

Note: This chapter begins where the chapter 6 left off. If you skipped ahead or don't have the right version of the project app handy, just open the starter project for this chapter to start off in the right place.

The floor node

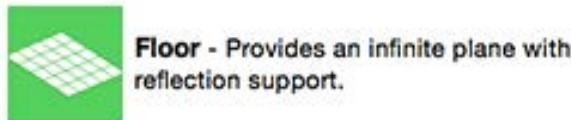
Before you add cameras to the scene, you need something to show. Building is a bottom-up process, and games are no different, so start with the floor.

The **floor node** is a special node with some interesting features. It's basically a plane that stretches infinitely in all directions, so your floor can be as large as you want, which is pretty cool. That's not its best feature, though. It *also* has the ability to act as a reflective surface.

If you let those creative juices flow for a bit, you'll realize the floor node can be so much more than just a simple floor. It could be a serene lake, quicksilver slick or glossy black dance floor.

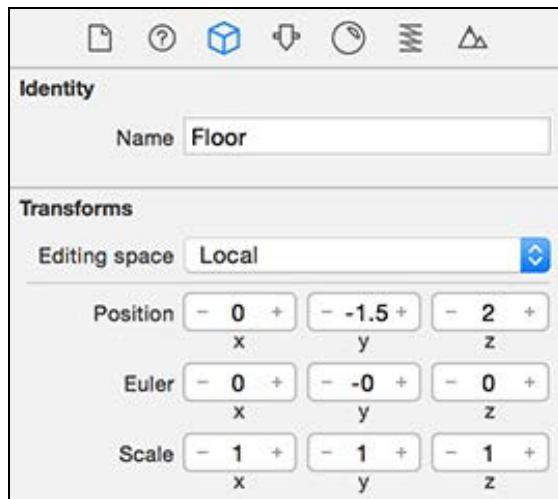
Add a floor node

Now it's time to cut the chatter and get to laying down that oh-so-important floor node. Open your project and select **Game.scn**. This should open the scene editor. From the Object Library on the bottom-right, drag and drop a **Floor** into the scene:



Select the newly added floor in the scene graph, and open the **Node Inspector** in the top-right.

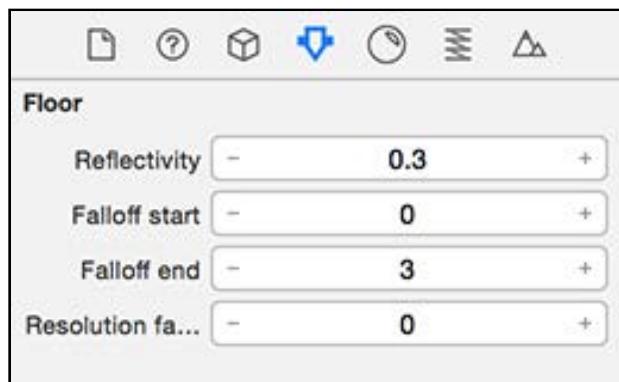
Change the name to **Floor**, and adjust **Position** to $(x:0, y:-1.5, z:2)$. The steppers — the plus and minus buttons — may not offer adjustments that are precise enough, so you'll have to either manually type in the values or click and drag the value itself to change it. You should end up with something like this:



Every node you add to the scene will have specific properties, so take a moment to acquaint yourself with Node Inspector:

- **Identity:** This is the node's handle, and it's critical that a proper identity is in place. When you start working on your scene in code, you'll use the **Name** to identify and find the desired node.
- **Position:** This defines where the node is placed within the scene, and it's relative to the parent node.
- **Euler Angles:** These allow you to control the rotation of your node relative to its parent node. Euler angles control pitch, yaw and roll, allowing you to specify a precise rotation angle around each axis.
- **Scale:** This allows you to apply overall scaling to your node's contents and children, again relative to the parent node. Changing the size of your node is an example of how you'd use scale.

Next, select the **Attributes Inspector**, which should be a tab to right of the Node Inspector. Change **Reflectivity** to **0.3** and **Falloff end** to **3**:



Note: The **Attributes Inspector** is contextual, so its contents are based on the type of node you've selected. Because you're working with a floor node, only properties that specifically apply to a floor will show.

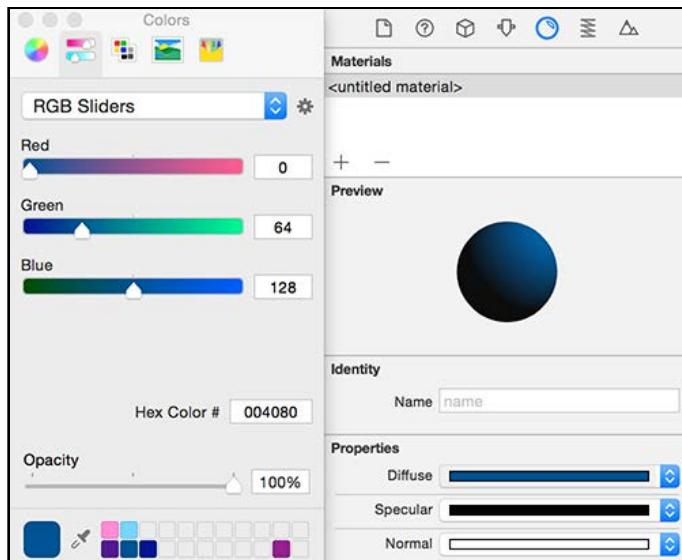
Speaking of floor-specific properties, these are what you should see:

- **Reflectivity:** This controls the reflectiveness of the surface. A value of 1.0 would make the floor a perfect mirror, and a value of 0.0 would make the floor completely devoid of reflection.
- **Falloff Start/End:** These two properties adjust the reflection's gradient — specifically, where it starts and ends. When SceneKit renders reflections off the floor, it applies an opacity gradient that fades parts of the reflection based on the distance between object(s) and the floor; closer objects render a sharper reflection, while more distant objects have more obscure reflections.

- **Resolution Factor:** This defines the crispness of the reflection's resolution. For example, a value of 1.0 would create a "pixel perfect" reflection, while a value of 0.1 would create a rather rough, pixelated reflection. These calculations are costly, so remember that you'll need to find a balance to optimize performance.

So you've got your floor, but without color, it's hard to see. So, select the **Material Inspector**, and under **Properties**, click on **Diffuse** to bring up the color picker. Navigate to the **Color Sliders** tab, find the drop-down and select **RGB Sliders**.

You can either set each color component separately, using (Red:0, Green:64, Blue:128), or you can set all three at once by setting **Hex Color #** to 004080. Whichever approach you take, this should be the result:



Heads-Up Display (HUD)

Besides the dark floor, there's nothing in your scene to look at, so before moving on, how about you give yourself something to see? :]

Add a HUD

As mentioned in Chapter 6, "SceneKit Editor", you're making use of the same game utilities you played with in the last section. Here you'll use them to add a heads-up display (HUD) to your scene, and this HUD will give players a quick overview of their available lives and score.

Open **GameViewController.swift** and add the following line of code to `setupNodes()`:

```
scnScene.rootNode.addChildNode(game.hudNode)
```

This line of code will add the HUD from the game utilities to your scene. `hudNode` is a plane with some images and labels that display the player's remaining lives and score.

Next, add the following to the body of `renderer(_ , updateAtTime)`:

```
game.updateHUD()
```

This line updates the HUD on every frame by calling the `updateHUD()` on the game helper.

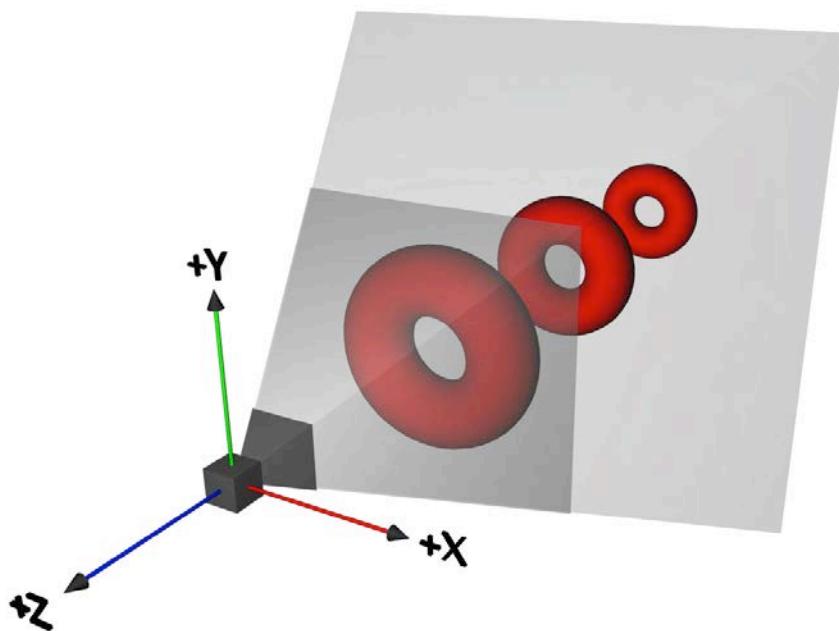
Note: Remember the HUD is somewhat special because you add it to the scene in code. This means you won't see the HUD in the scene editor when designing your scene visually, because you create it at runtime.

Cameras

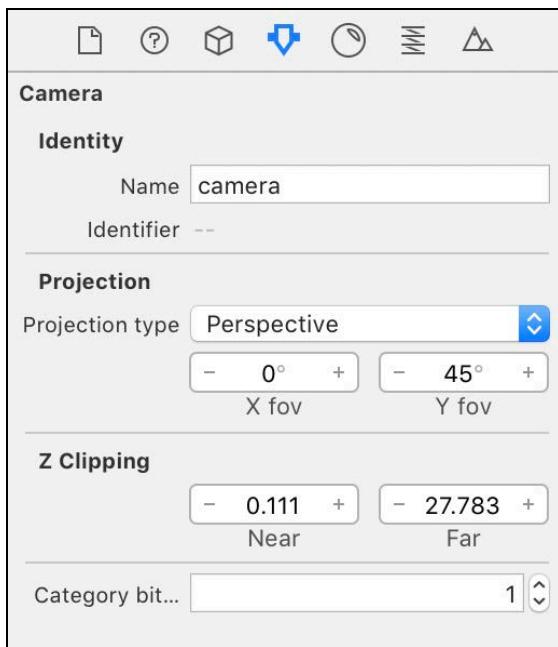
Okay back to the subject at hand — cameras! SceneKit offers two types of cameras: *perspective* and *orthographic*.

Perspective camera

Perspective cameras are commonly used for 3D games like first-person shooters. They give you depth perception so that distant objects appear smaller than close objects.



Here's what the **Attributes Inspector** looks like for a perspective camera:

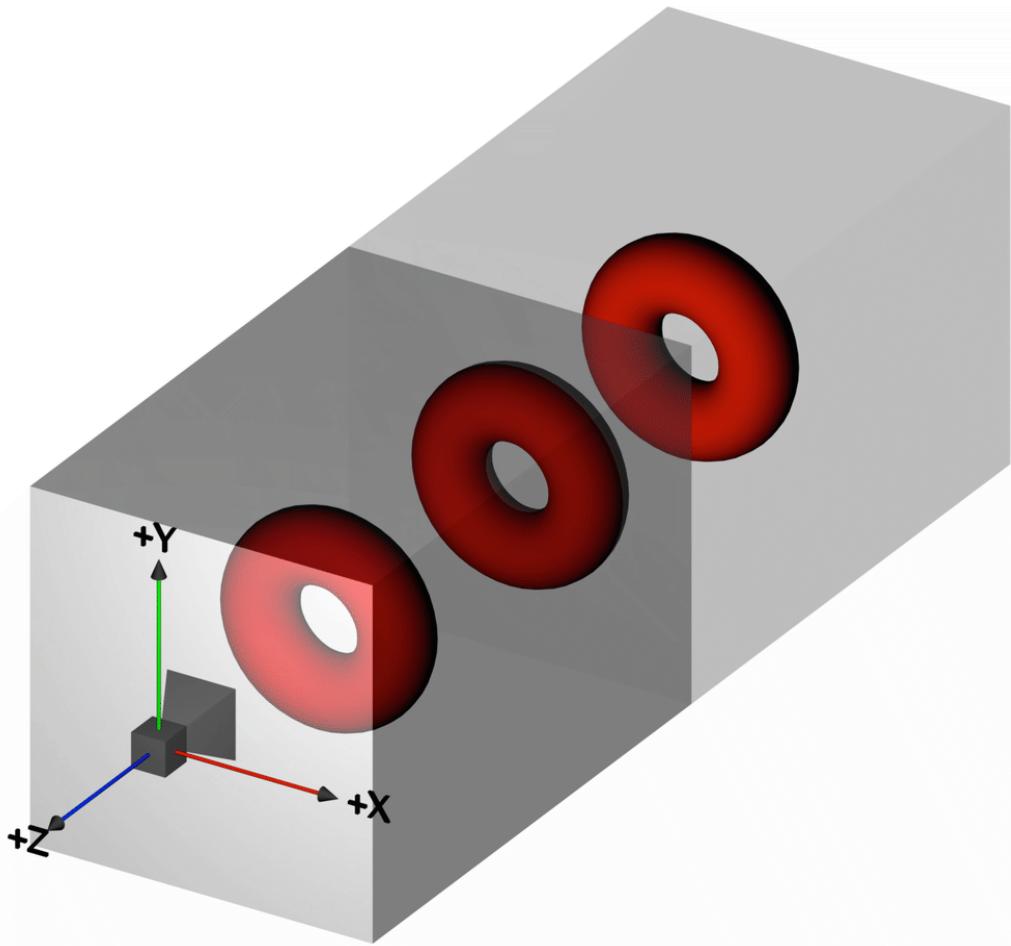


Take a moment to review the most important attributes of a perspective camera:

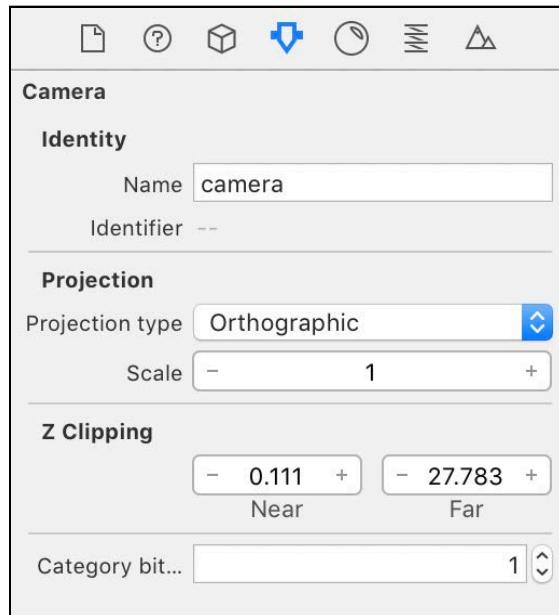
- **Identity:** This is the identity of the camera node within the scene graph.
- **Projection:** The x and y fields of view (FOV) determine the camera's viewing angle. When both values are **0**, SceneKit will default to a 60-degree vertical angle (Y FOV) and adjust the horizontal viewing angle (X FOV) to fit the screen's aspect ratio.
- **Z Clipping Range:** This determines the frustum depth range, which defines how close or far objects need to be to the camera in order to render. Objects closer than the **Near** distance and further than **Far** distance from the camera are clipped and not rendered.
- **Category Bitmask:** This allows you to prevent objects from being rendered, as if you put a mask on them or the camera lens.

Orthographic Camera

Orthographic cameras are becoming more popular, and you can see them in games like *Crossy Road* and *Pacman256*, where objects near and far from the camera all appear to be the same size.



Here's what the **Attributes Inspector** looks like for an orthographic camera:



Get to know the important attributes for an orthographic camera:

- **Identity:** This is the identity of the camera node within the scene graph.
- **Projection:** When working with an orthographic camera, the projection scale allows you to increase or decrease the size of your view. Picture this as controlling the zoom of your camera. Remember that with an orthographic camera, objects that are the same size will appear to be the same size, regardless of distance from the camera.
- **Z Clipping Range:** This behaves the same as it does for a perspective camera and determines the frustum depth range.
- **Category Bitmask:** Similar to a perspective camera, you use this mask to control which objects show in your camera's view.

Camera visual effects

With iOS 10 comes a massive helping of goodies for the SceneKit camera in the form of new shader effects for SceneKit's camera.

Now you can channel your inner Spielberg and take your 3D games to the next level of realism. Take a closer look.

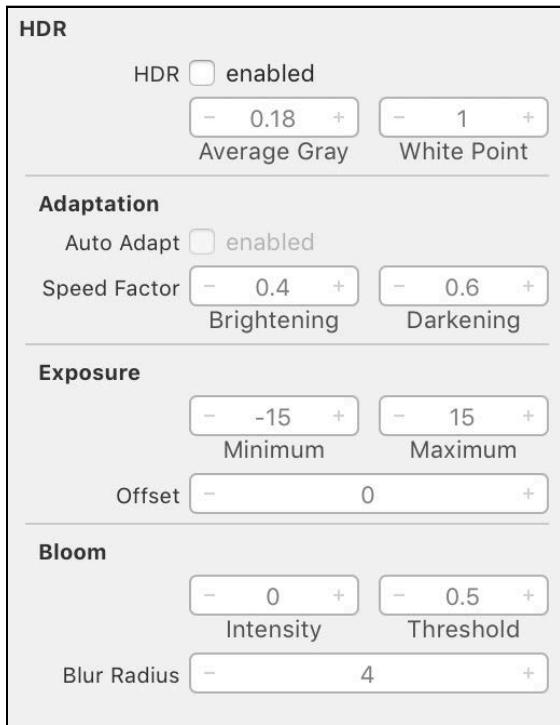
HDR effects

Arguably the coolest new effect is the **High Dynamic Range** (HDR).

HDR is like magical laundry soap for your game. It promises to make your bright colors brighter, your dark colors darker and will never fade those mid-range colors. It truly is fantastic stuff! :]

It allows you to display a much wider range of colors to let you make your world more life-like to the human eye than ever before.

In Xcode 8, the **Attributes Inspector** for camera nodes has a new **HDR** section:

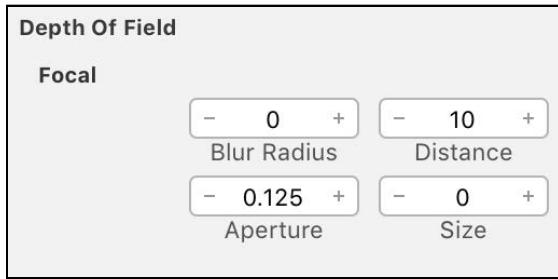


Here's a breakdown of all the available properties:

- **HDR:** Here you can specify whether HDR effects should be applied to a scene or not. The **Average Gray** setting specifies the luminance level that will be used as the mid-point for a tone mapping curve. **White Point** specifies the luminance level to be used as the upper end of a tone mapping curve.
- **Adaption:** An effect that's similar to how it looks when your eyes adapt after stepping inside after being out in the bright sun. Here you can enable **Automatic Exposure Adaption** for a scene. **Brightening** specifies how fast exposure transitions from dark to bright areas. The **Darkening** setting specifies how fast exposure transitions from bright to dark areas.
- **Exposure:** Essentially controls the brightness and darkness levels of a scene. Here you control the **Minimum** and **Maximum** exposure levels used in tone mapping. **Offset** allows you to control a logarithmic bias that adjusts tone mapping.
- **Bloom:** Creates a hazy blur around bright, highlighted areas. Here you control the **Intensity** of the bloom with **Threshold**, which controls the brightness level of the blur. **Blur Radius** specifies the thickness of the band of blurred pixels around affected areas.

Depth of field effects

This cool effect has been available for some time now. It controls the aperture of your camera, allowing you to introduce blurriness based on depth perception of a scene by controlling the focal length and size. Blur can add a great sense of realism to your scene, but it does come at a high performance cost.



These are depth of field's properties:

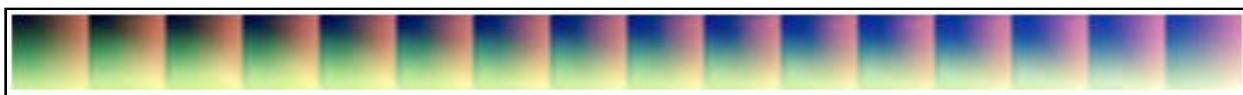
- **Distance:** This controls the distance of the focal point from the camera.
- **Size:** This controls the size of the focal point. Objects within the focal point will appear sharp, whereas objects outside will be blurred.
- **Blur Radius:** This controls the maximum amount of pixel blur that will apply to areas falling outside of the focal point.
- **Aperture:** Controls a factor that determines the transition between in-focus and out-of-focus areas.

Post-Processing effects

Post-processing effects were also introduced in iOS 10 and give you even more control over the final result of the rendered scene.



- **Vignetting:** This effect darkens the edges and corners of the scene. **Intensity** controls the magnitude and **Power** controls the amount of the scene that the effect will darken.
- **Color Fringe:** This is also known as *Chromatic Aberration*, which is a lens-based defect that occurs in optics because the refractive index of glass varies with different wavelengths. This effect recreates this defect by introducing a color fringe between contrasting colors. **Strength** controls the magnitude, and **Intensity** controls the blend factor for fading the fringing effect.
- **Color Grading:** This allows you to change the final color of the rendered scene. **Saturation** is an adjustment factor of the overall color saturation. The **Contrast** setting is an adjustment factor that gets applied to the overall visual contrast of the rendered scene.



Note: You can also provide a custom color table texture to be used to apply color grading to a rendered scene. This ultimately gives you greater capability to control color than ever before.

Motion blur effects

Another awesome effect for the camera in iOS 10 is the **Motion Blur** effect!



There's only one available property:

- **Motion Blur Intensity:** applies a blurred effect on all objects in the scene that are currently in motion. **Intensity** controls the intensity of the blur.

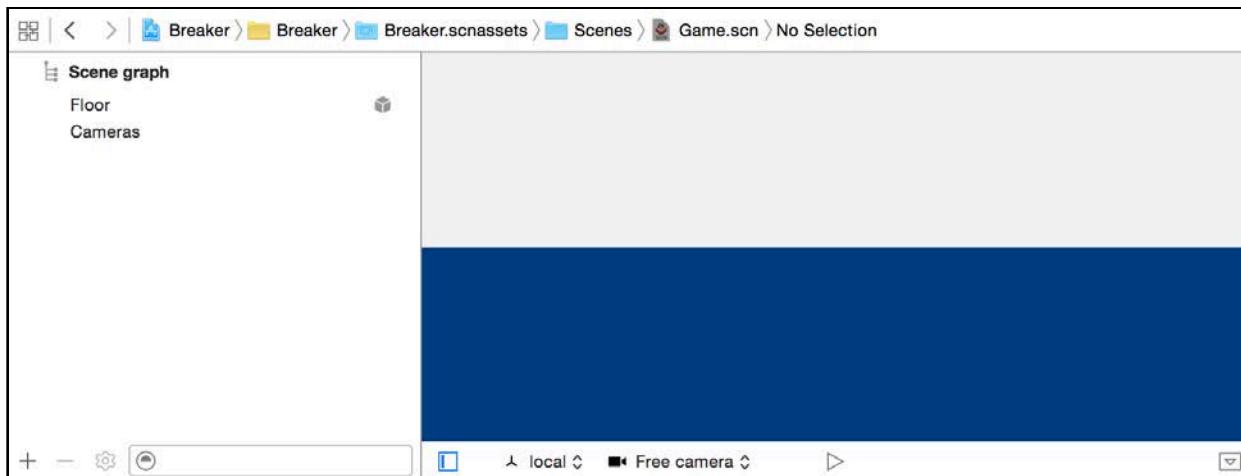
Add a camera node

You hung in there for all those little explanations, and now, dear reader, you're going to reward your studious ways by adding cameras to your scene!

Select **Game.scn** to open up the SceneKit editor.

Start off by selecting the **+** button in the bottom-left of SceneKit editor toolbar. This will create an empty node named **untitled**. Rename it to **Cameras** and know that it will be home to your camera nodes.

Note: To name a node, you can select and rename it within the scene graph by pressing **Return**. Alternatively, you can select the node, open the Node Inspector on the right, and then set its **Name** under the Identity section.



From the Object Library on the bottom-right, drag and drop two **Camera** nodes into your scene.

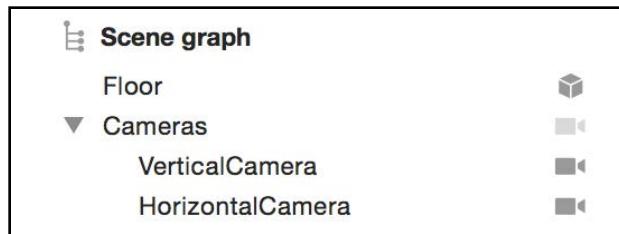


Camera - Provides a camera that can be used as a point of view to render the scene.

Name one **VerticalCamera** and the other **HorizontalCamera**. You'll learn why you need two cameras later in this chapter.

TL/DR: dual cameras give you fine-grained control that lets you make your game look a certain way when it's viewed in landscape and portrait orientations.

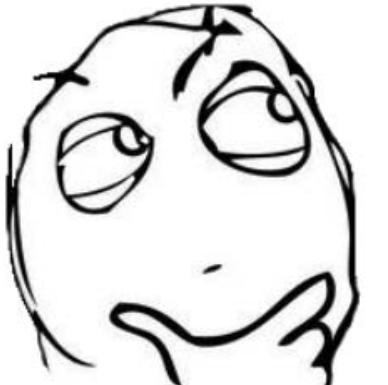
Make both new cameras children of **Cameras**:



Note: Nodes all need unique names, so it's important to be purposeful and give them identities that you'll remember under pressure. You'll get a feel for how important identities are when you find a node within the scene from your code.

Configure the vertical camera

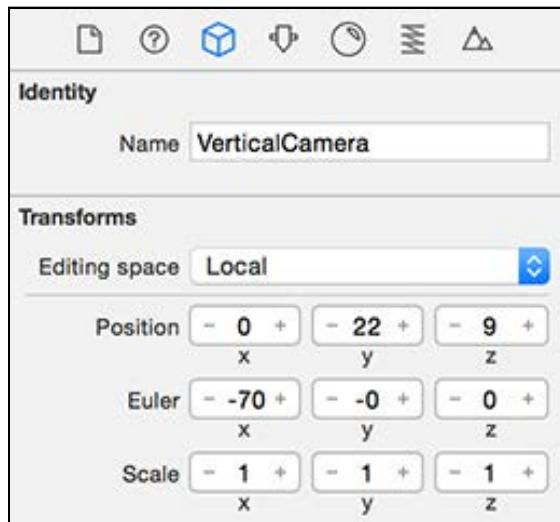
Cameras, by default, have no idea what you want them to look at, so after making them comes pointing them in the right direction.



X's and Y's and Eulers, oh my!

Select **VerticalCamera** inside the scene graph and open the Node Inspector. Set the **Position** to $(x:0, y:22, z:9)$. Next, set the **Euler** angles to $(x:-70, y:0, z:0)$. This places the camera **22** units high and **9** units away (towards you) from the center of the scene. It then tilts the camera **70 degrees** downwards to give the player a spectacular bird's eye view of the scene.

You should have something like this:

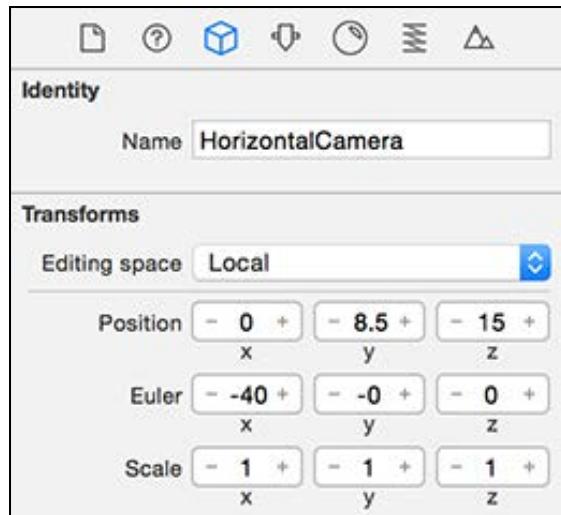


Configure the horizontal camera

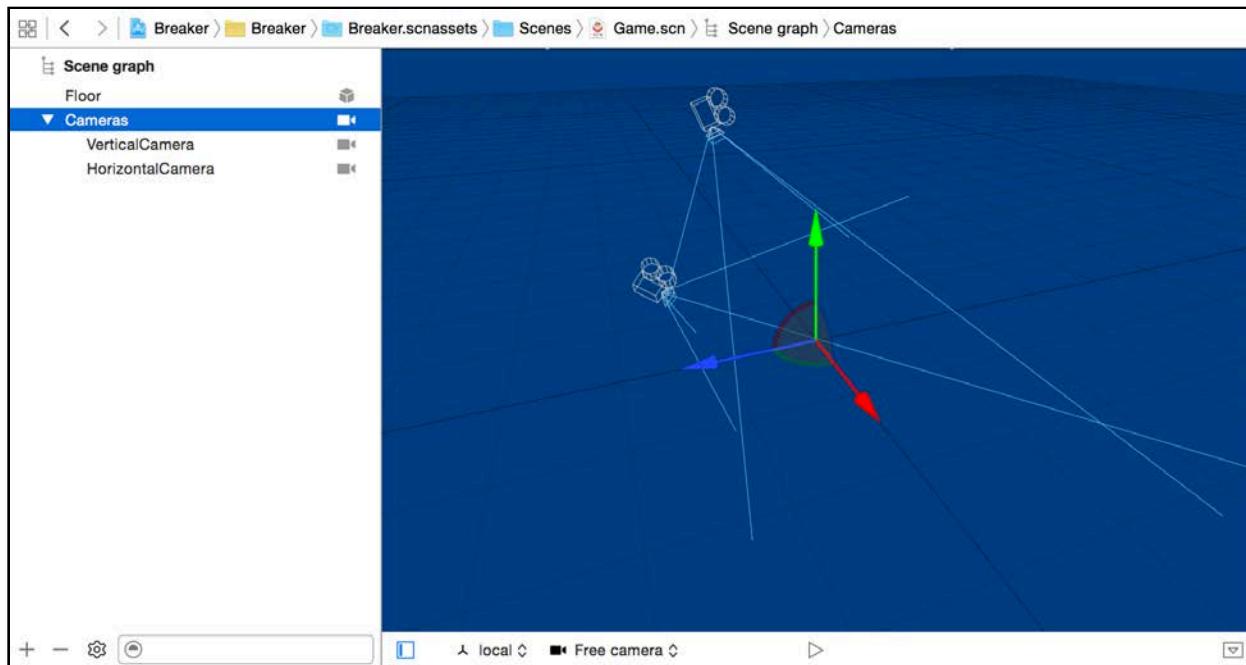
Select **HorizontalCamera** in the scene graph and bring up the Node Inspector. Set the **Position** so that $(x:0, y:8.5, z:15)$. Next, set the **Euler** angles so that $(x:-40, y:0, z:0)$.

This places the camera **8.5** units high and **15** units away from the center of the scene. It then tilts the camera **40 degrees** downwards to give the player a nice wide-angle view of the scene.

Your config should look this:



When comparing the two cameras, you'll notice that the horizontal camera is closer and at a lower angle than the vertical camera.



Node binding

Just because you've added cameras doesn't mean they do anything. You need to bind your code to them so that you can actually see your scene through them.

Binding to the cameras

Add the following properties to GameViewController inside **GameViewController.swift**:

```
var horizontalCameraNode: SCNNode!
var verticalCameraNode: SCNNode!
```

This defines two camera nodes that you'll use to keep track of your cameras in the scene. Note that the nodes use a similar name to the cameras themselves.

Add the following to the beginning of setupNodes():

```
horizontalCameraNode = scnScene.rootNode.childNode(withName:
    "HorizontalCamera", recursively: true)!
verticalCameraNode = scnScene.rootNode.childNode(withName:
    "VerticalCamera", recursively: true)!
```

Remember the scene file is already loaded, so your mission here is just binding properties via code to the camera nodes inside the scene. To do this, you have to find them inside of `scnScene.rootNode` by looking with `childNode(withName:recursively:)`. Every node has this functionality that allows you to find a particular child node by its identity. You'll use `childNode(withName:recursively:)` a lot!

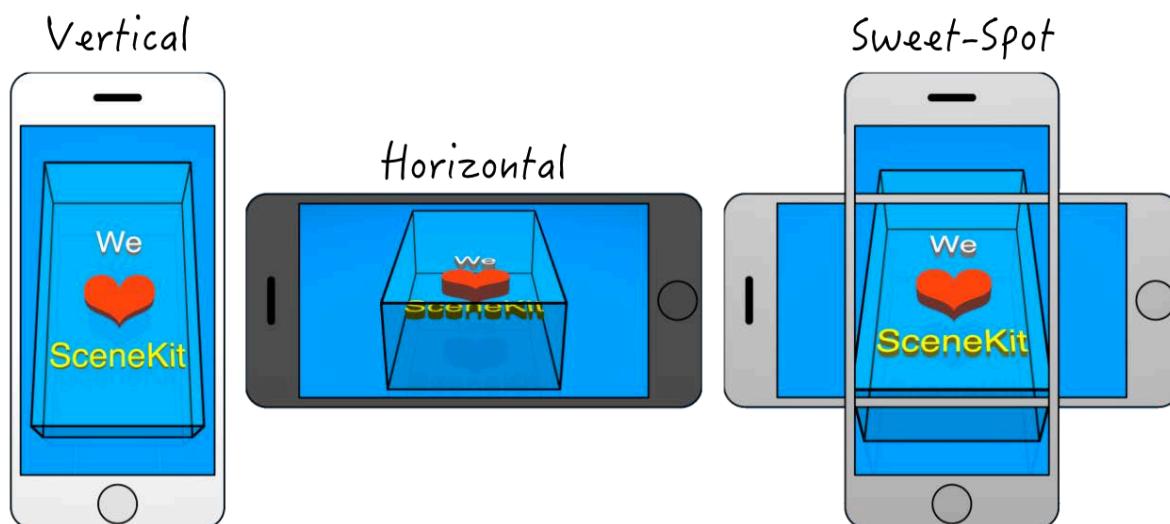
By setting the `recursively` parameter to `true`, you tell the method to drill down into the node's entire subtree to find the requested child. It's important to name your nodes uniquely when you use this functionality.



Device orientation

You're probably still craving more detail about the two cameras. Well, hunger no more because you'll learn a neat trick to overcome a common problem your game could face when the user decides to rotate their device.

As the device changes orientation, the screen's real estate changes too. Instead of trying to make a single camera that finds the "sweet spot" between both orientations, you create two separate cameras, each of which maximizes the available "real estate".



Note: With a single camera view, the sweet spot approach could utilize all the real estate in both orientations, but the cost is that the user may lose view of part of the scene in one of those orientations.

Track device orientation

Each orientation change triggers an event, and you need the game to actively switch between your two cameras during these events.

To achieve that, override `viewWillTransition(to size:, with coordinator:)` inside `GameViewController` with the following:

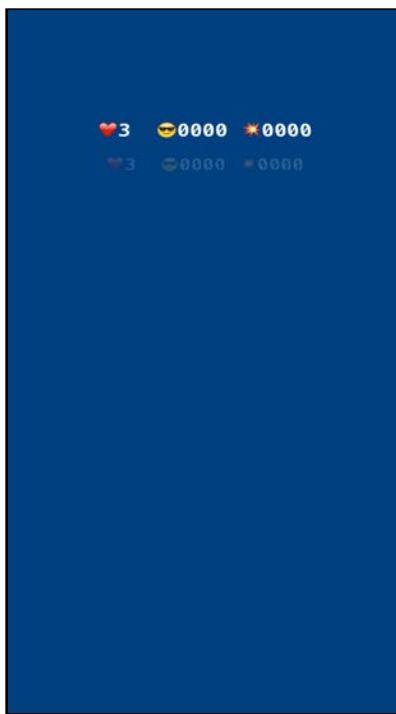
```
// 1
override func viewWillTransition(to size: CGSize, with coordinator: UIViewControllerTransitionCoordinator) {
    // 2
    let deviceOrientation = UIDevice.current.orientation
    switch(deviceOrientation) {
        case .portrait:
            scnView.pointOfView = verticalCameraNode
        default:
```

```
        scnView.pointOfView = horizontalCameraNode  
    }  
}
```

Take a second to understand this code:

1. By overriding `viewWillTransition(to:with:)`, you tell the game to run code whenever the device changes size. Inside this method, you need to inspect the device's orientation to determine the new orientation.
2. Here, you switch based on the `deviceOrientation` that you get from `UIDevice.current().orientation`. If the orientation is about to change to `.portrait`, you set the view's point of view to be `verticalCameraNode`. Otherwise, you set the point of view to be `horizontalCameraNode`.

You're done! Build and run and reap the rewards:



You should now see a reflective floor with a HUD hanging in mid-air. Be sure try out different screen orientations and take note of how the point of view changes.

Note: Instead of having the traditional HUD overlay; this time the HUD is placed at position `(x:0, y:-0.3, z:-9.9)` within the game scene. The HUD appears somewhat distant, and slightly above the reflective floor in relation to the bird's eye view of the camera. The effect might seem peculiar at first, but its magnificence will become more apparent as you build the rest of the scene in the next chapter.

Where to go from here?

Stellar performance! You've reached the end of this chapter, which means you're now one step closer to completing your game.

Here's what you touched on in this chapter:

- **Cameras:** You learned about the two types of cameras available in SceneKit: perspective and orthographic. You even know the differences between them!
- **Node Inspector:** You learned about the Node Inspector and how it's used to position, rotate and scale any node. You used it to position both the cameras and the floor nodes.
- **Floor Node:** As an added bonus, you learned about the floor node and its super powers of reflectivity and perpetuity.
- **Attributes Inspector:** You also now know that the Attributes Inspector is contextual, and it changes for each type of node. If you're working with a camera, you'll see camera-related properties, or if you're working with a floor, you guessed it, you'll see floor-related properties.
- **View Points:** Last but not least, you learned a nifty little trick to switch between different camera view points based on the device orientation.

Stay tuned for the next chapter, where you'll add some light to the scene! As they say in the movie industry, lighting is everything, and that applies to 3D games too.

Note: You can find the final project for this chapter under the **projects/final/** folder.



Chapter 8: Lights

Chris Language

Getting started

Lighting is often the “secret sauce” of design. Ask any photographer what’s most important to capturing a good shot, and they’ll tell you it’s all about the lighting.

The same is true of any game. Sure, you could just illuminate the entire scene like a vintage console game and play would still go on. However, as you observed in Chapter 7, “Cameras”, lighting changes the look and feel of a game.

Without thoughtful lighting, your objects appear flat and dull; users will also struggle to see the finer details of objects in the scene.

Before you start playing with lights, you need to understand how they work in a 3D rendering engine.

When you add a light source to the scene, the rendering engine kicks in to determine how light should reflect off the scene’s objects. It factors in:

- Color
- Direction
- Position

All calculations are based on each object’s **surface normal**.

Feeling a bit lost? Let’s shine some *light* on the subject! :]

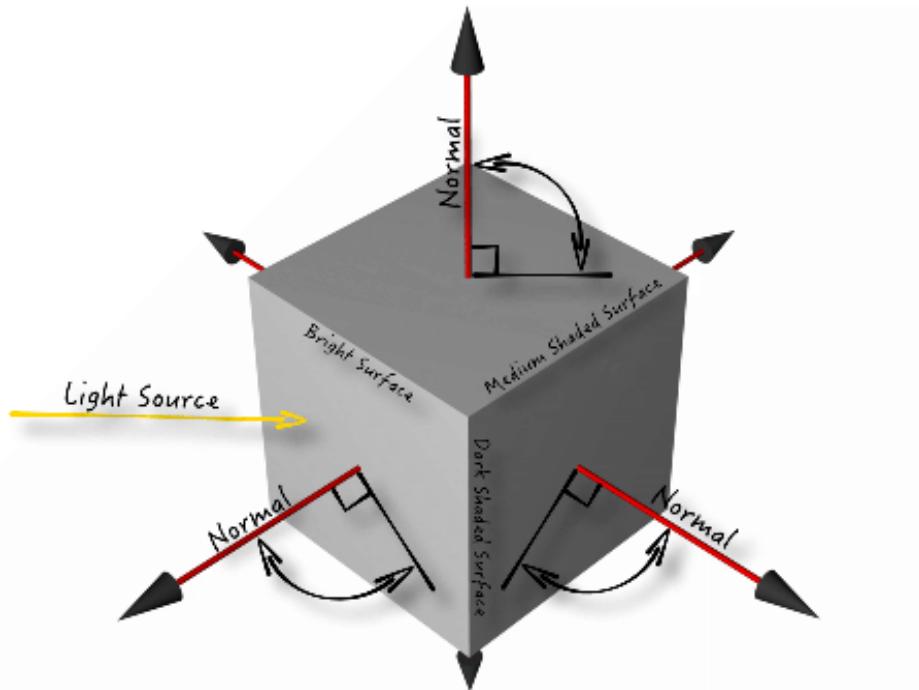


Surface normal

Before you begin, it's important to understand the concept of a **surface normal**.

You can think of a surface normal as an imaginary vector (or line) that's perpendicular to the surface of a polygon, or in game design terms, a node.

In the 3D world, it's a rather crucial vector that is used not only for lighting purposes, but also for determining whether a polygon is facing the camera view. Perhaps this is a good time to share a diagram:



There are a couple of points to note:

- **Normal vectors:** See those red vectors? Those are the imaginary surface normals. Note how each one forms a perfect 90-degree angle to the surface of the cube.
- **Light source vector:** That's the yellow ray of light coming in from the left side.
- **Surface shading:** See how each surface has different shading? Take note of the angle between the light source vector and each surface normal. Smaller angles yield a brighter surface, while larger angles yield a darker and shadier surface. The rendering engine performs that calculation to determine how bright or dark a surface should be.
- **View source vector:** The camera is the view source because it's the point of view into the scene. When you see this term, think of a vector that points from the camera into the scene. In the diagram above, the view source vector would beam right off the page into your eyes.
- **Surface culling:** Notice how only the surfaces that have a part of their surface normal pointing towards the view source — your eyes in this case — are visible. That's exactly how the rendering engine determines which surfaces to cull (not draw) to save precious drawing time. Surfaces on the rear of the cube are not drawn since their normals point away from the view vector.

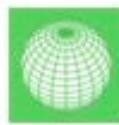
Sphere nodes

Your game needs some balls — well, it'll actually be a single **sphere node** if you want to get technical. Aside from being an essential component of game play, the ball also gives your scene a subject to illuminate.

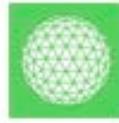
Note: You can find the starter project for this chapter under the **projects/starter/Breaker** folder. It picks up where the previous chapter left off.

Adding a sphere node

Open your project and select **Game.scn**. Under the Object Library, drag and drop a **Sphere** into your scene.

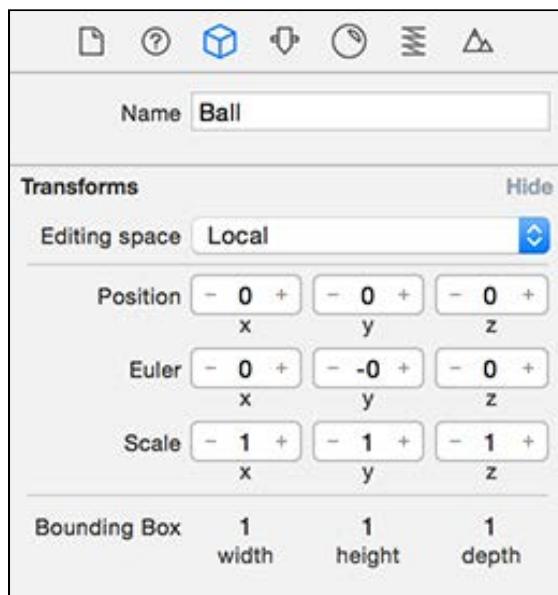


Sphere - Provides a sphere geometry.



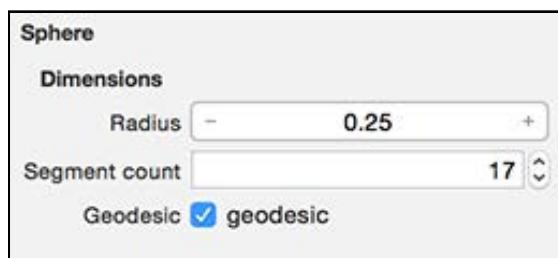
Geosphere - Provides a geodesic sphere geometry.

Make sure the sphere node is selected in the scene graph, then select the Node Inspector. Enter **Ball** for **Name**, and then zero out the **position** so that the ball sits smack-bang in the middle of the scene.



Next, open the Attributes Inspector. You want to shrink the ball down to size because the default radius of 1.0, produces a massive sphere.

Change **Radius** to **0.25**, **Segment count** to **17**.

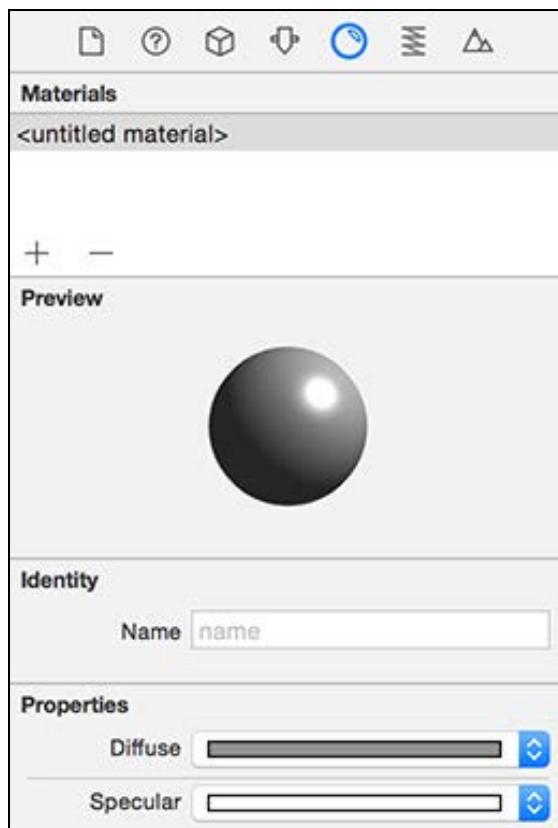


Note: Both the sphere and geosphere are essentially the same things, the difference being the state of the geodesic checkbox, which tells the rendering engine how to construct the sphere.

Sphere nodes have the following specific attributes:

- **Radius:** As you might have guessed, when you change the radius, you change the size of the sphere.
- **Segment count:** SceneKit approximates curved surfaces by using many small, flat polygons joined together in a mesh. In effect, a sphere comprises many smaller polygons. Segment count controls the number of segments to use when generating the sphere's geometry. The more segments, the smoother the sphere and the higher the polygon count. The higher the polygon count, the more processing time it takes to render. Keep this setting as low as possible.
- **Geodesic:** You'll notice that SceneKit provides two different types of sphere nodes, the difference being how the polygon mesh is generated. By default, the surface of the sphere is simply a grid of rectangles, but a geodesic sphere uses equally sized *triangles* to generate its mesh. This setting affects how you use **Segment Count** to break down the sphere into smaller polygons.

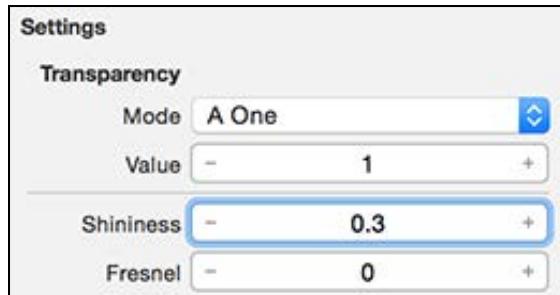
Next, select the **Material Inspector**. Change **Diffuse** to a dark gray by setting the **Hex Color #** to **7F7F7F** in the **RGB Sliders**. Next, change **Specular** to **White** by using the dropdown. You should have something like this:



Note: Specular controls how shiny and reflective your material is, with white being reflective and shiny and black being dull and matte. In this chapter,

you'll just dabble with this setting but will go more in-depth with it later in the book.

Further down in the Material Inspector, find the **Settings** section and change **Shininess** to **0.3**.



Once you're done, select **HorizontalCamera** as your active viewpoint by selecting it in the toolbar at the bottom of the scene editor, and your scene should look something like this:



But something isn't quite right; the ball is completely devoid of shine. No lights = no shine. You'll add lights shortly!

Bind to the ball

Before you add any lights, you need to add some code to bind the ball in the scene to a property in your view controller, so that you can access it via code.

Open **GameViewController.swift** and add the following property to **GameViewController**:

```
var ballNode: SCNNode!
```

To bind this property to the ball in the scene, add the following code to the end of **setupNodes()**:

```
ballNode = scnScene.rootNode.childNode(withName: "Ball", recursively: true)!
```

The method `childNode(withName:, recursively:)` does a recursive search for a node named *Ball* in the root node of the scene. Once found, it binds *Ball* to `ballNode` for easy access later on.

Lights

Congrats! You can finally play around with lights. SceneKit has a few different types of light sources: omni, directional, spot, ambient, IES and light probe.

Whoa, with so many, how do you pick? :]



Omni light - Illuminates the scene from a point in every direction.



Directional light - Illuminates the scene in a specific direction.



Spot light - Illuminates the scene from a point and spreads out as a cone.



Ambient light - Illuminates the scene equally in every directions.



IES Light - Illuminates the scene with an IES profile.



Light Probe - Sample the lighting at a specific location.

Although the built-in descriptions are pretty good, I'll elaborate a bit on each type to give you that ninja edge:

- **Omni light:** That bright ball of light in the daytime sky — the Sun — is basically an omni light, meaning it emits light in all possible directions from a single point in space. However, when trying to mimic the sun in a 3D game, an omni light is generally not the best type to use. It's a lovely effect that's well-suited for things like a burning candle or a light bulb hanging from the ceiling.

- **Directional light:** This type emits parallel rays of light in a particular direction. It's highly recommended to use this type when you're mimicking sunlight in your 3D game.
- **Spot light:** This type of light is also directional, but the light emits from a single point in space and spreads out in a cone shape. Use it for a more focused light source, for instance, a crazy night time car chase where a helicopter is tracking fleeing bad guys in a car.
- **Ambient light:** The ambient light is a source that controls the overall brightness of your scene. Another way to think of ambient light is a way to control the darkness level of the shadows in your scene.
- **IES light:** Also known as a photometric light source. It utilizes real-world physical measurements to define a light profile that includes shape, direction and intensity of illumination. This information is stored in a file using standard format defined by the *Illuminating Engineering Society (IES)*. You'll find that many manufacturers publish these IES files based on lighting characteristics for their products. To enable such a light source, you'll need to provide a URL to a proper IES file. You'll also have to set the light type to **SCNLightTypeIES**.
- **Light Probe:** A light probe isn't an actual light source. Instead, when placed in a scene, it will sample the color and intensity of the illumination it receives at a single point from all possible directions. This information is then used to apply shading to materials based on their position within a scene. For example, placing a white object close to a brightly colored wall would typically reflect the radiated color of the nearby wall on the surfaces facing the colored wall.

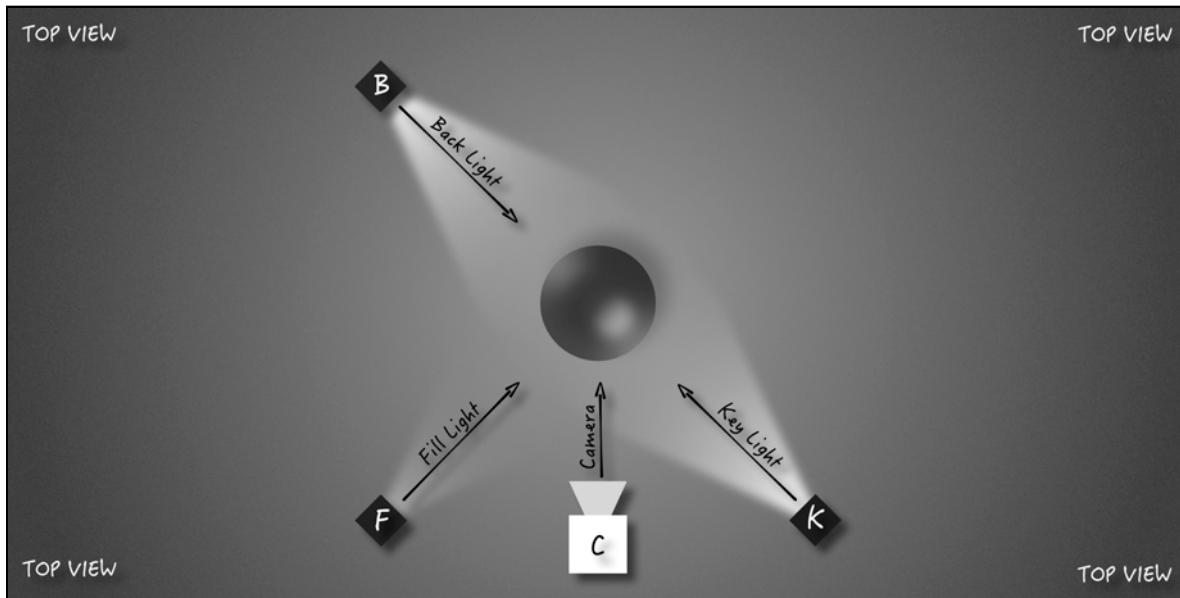
Note: Typical **SCNLight** properties do not apply to **Light Probes**, as they don't actually generate light. It's a good practice to place light probes across the entire scene so that the probe's lighting information can be used during rendering.

Three-point lighting

One of the secrets to making 3D graphics more realistic is to make use of real-life lighting techniques.

In traditional photography, a very popular and highly effective lighting technique is the three point system. As its name suggests, there are three points of light. Sometimes there are two lights on either side and another illuminating the subject head on, and then some configurations call for backlighting. Regardless of setup, three lights will fully illuminate the subject and minimize shadowing.

Here's an example of what a three-point lighting setup looks like:



It's good to remember that you can add and control shadows on objects by adjusting the angles of the lights.

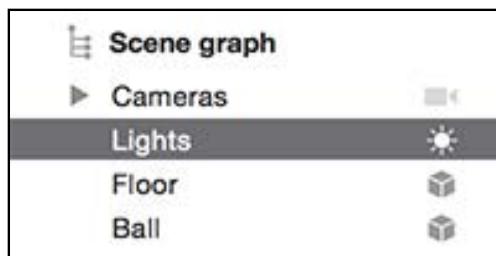
Take a closer look at each light source:

- **Key light:** This is the primary light source that will illuminate your subject from the front.
- **Back light:** This sits behind the subject, directly on the opposite side of your key light. Its purpose is to produce a rim light effect that highlights the edges of your subject.
- **Fill light:** This light source is placed perpendicular to your key light. Its main purpose is controlling the darkness level of shadows on the subject.

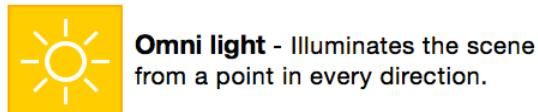
Add light nodes

It's finally time to add some lights to your scene, so let there be light! :]

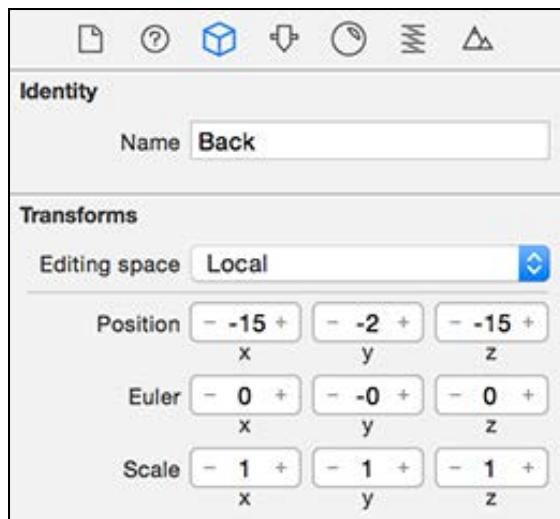
First, open up **Game.scn** and create an empty node under the scene graph by clicking the **+** button. Then, rename this new node to **Lights**. This will act as a group container for all the lights in your scene.



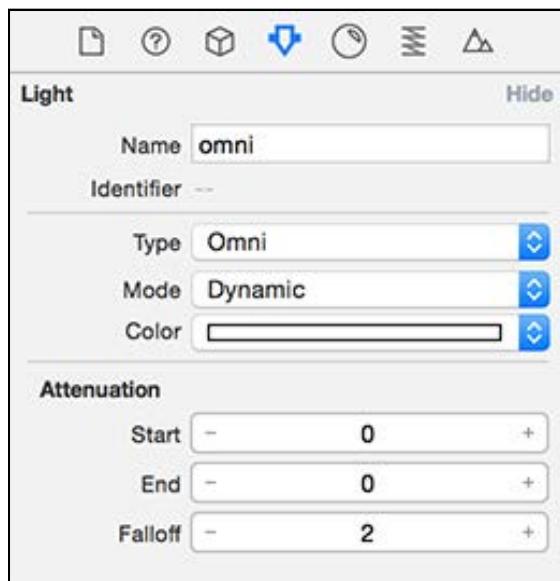
From the Object Library, drag and drop an **Omni light** into your scene. Make sure to move the light under the lights group node.



With the light node still selected, open the Node Inspector and rename the node to **Back**. Adjust **Position** so that (x:-15, y:-2, z:15). This represents the back light, so you are positioning it behind the ball. You should have something like this:



Select the **Attributes Inspector** to see the different attributes you can adjust for an omni light source.

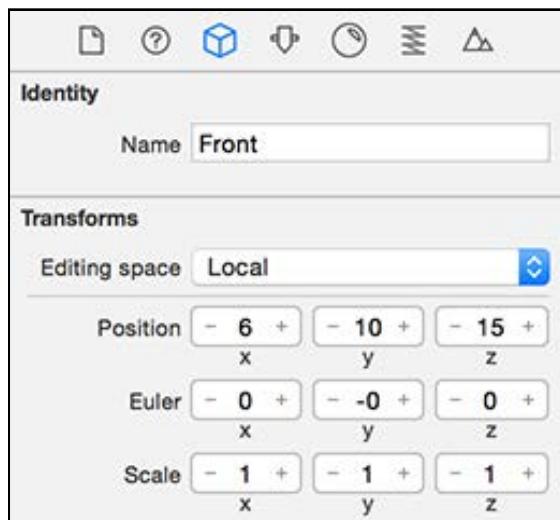


Keep the default settings for this exercise, but take a moment to learn what they do:

- **Mode:** You can choose from either **Dynamic** or **Baked**. For light sources that *move around* or apply their effects to nodes that move, you should use a *dynamic light*. For *static lighting*, use *baked* lighting where you create a light map texture in an external 3D authoring tool, and then the lighting effects will be applied to the textures of the objects in the scene. This option exists as an optimization. Although baked lights are less powerful, they require fewer computational resources.
- **Color:** This allows you to specify the light's color.
- **Attenuation:** This controls the intensity of the light source over a distance. When a node is closer than the start distance, the light applies its full intensity, whereas a node that is further than the end distance is not affected by the light at all. By default, the value is 0, meaning that attenuation will not apply. Sitting between the start and the end is the falloff, which is an exponential factor that controls how quickly intensity diminishes.

Add another light source by dragging and dropping another **Omni light** from the Object Library into your scene. Make sure you move it under the **Lights** group node as well.

Name this new node **Front** and set the **Position** to (x:6, y:10, z:15). This represents the front light (aka key light), and these settings place it in front of the ball.

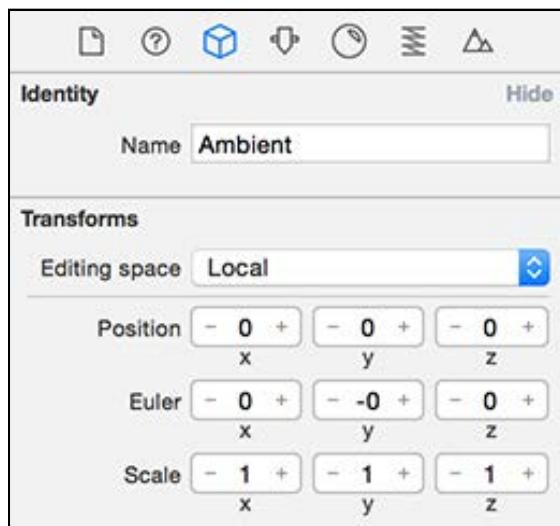


You're almost done, but the scene still needs an ambient light. You guessed it — to add, simply drag and drop an **Ambient light** from the Object Library.

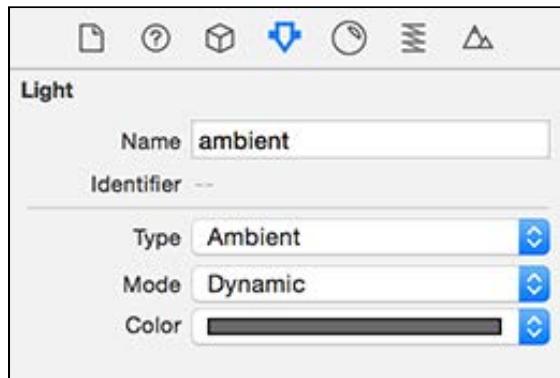


Ambient light - Illuminates the scene equally in every directions.

Again, make sure you move this new node into the **Lights** group node. You'll use this one to simulate fill light. Name it **Ambient**, and simply **zero out** the **Position** since position has no effect on the result for this kind of light.



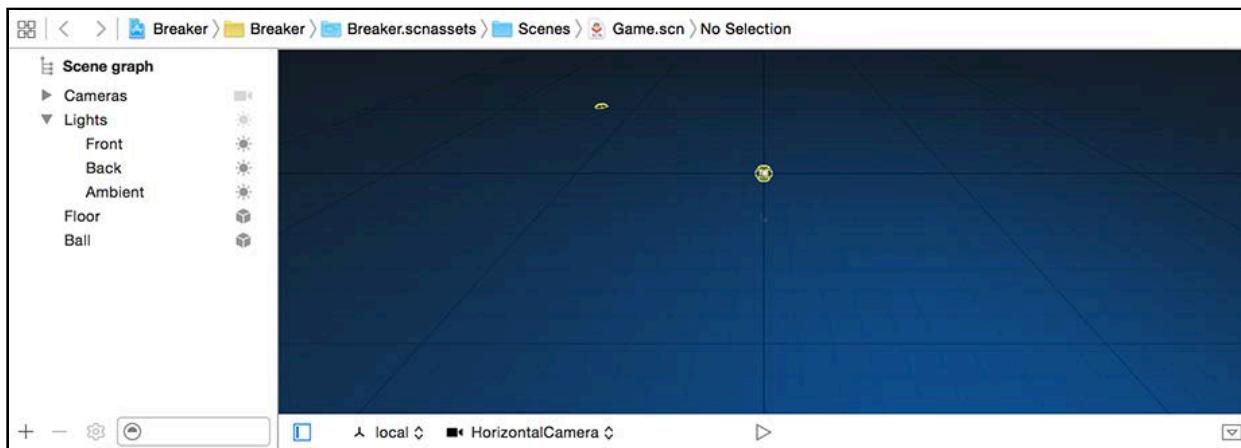
Now take a look at the Attributes Inspector for the ambient light.



You'll keep the defaults. Note that the only thing you can configure on an ambient light is color.

Finally! Have a look at the result. :]

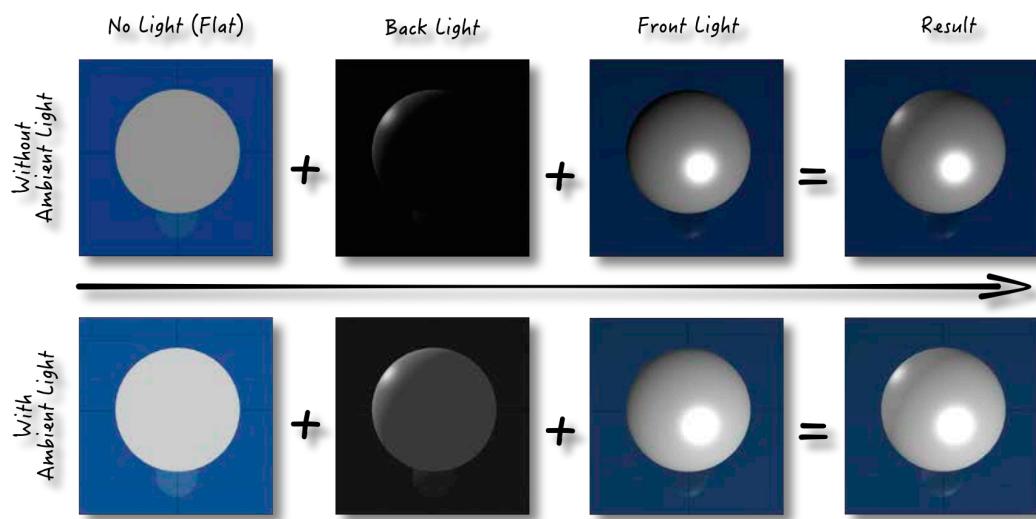
After adding all those lights to your scene, it should look something like this:



Take note of the scene graph structure, where all the lights show as children of the **Lights** group node.

Conclusion

Not only do you have the knowledge to implement the three-point lighting technique, but you also made it happen in your game. To understand how it works a bit better, take a look at the following diagram:

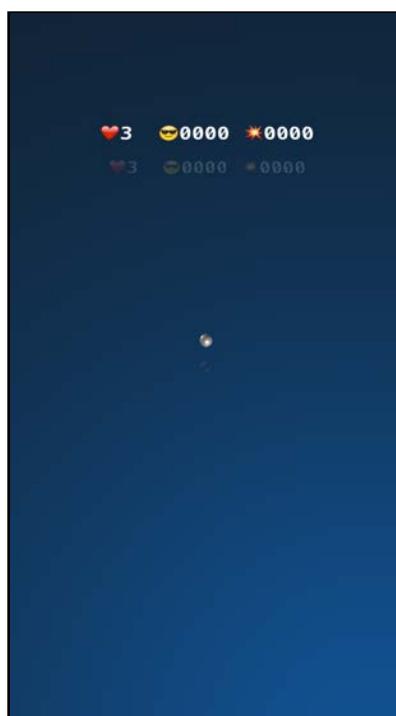


You can see the effect of each light on the ball, as well as the combined effect in the last column. Note that the first row has no ambient light, while the second row does have an ambient light. Take a closer look at each step:

- **No light:** When you started off, the ball was flat and dull because the scene had no light source. SceneKit uses a constant light in the absence of added light sources. Hence, you get a disk.

- **Back light:** As soon as you add a light to the scene, everything that's not in the light darkens. SceneKit stops applying constant light and starts using the added light sources to apply lighting and shading effects. This particular light currently acts as your backlight, creating a very subtle rim light effect around the edge of the ball.
- **Front light:** This lights up the ball even more, acting as the key light. Remember that the key light and backlight are opposite from each other in the scene.
- **Ambient Light:** This fills the whole scene with light, and its effect is especially notable in those dark, shadowed areas.

Build and run and see the fruits of your labor. :]



Well done, just look at how nice and shiny that ball is! Things are certainly starting to shape up.

Where to go from here?

You just finished yet another chapter. Good job! Clearly, there's no stopping you. :]

You've absorbed a lot of information in this chapter; Take a moment to recap:

- **Surface normal:** You now know how the surface normal plays its part in light calculations.

- **Sphere node:** You know more about spheres in SceneKit, and how you can adjust the size of a sphere by changing its radius.
- **Lights:** You learned about all the different types of light sources SceneKit has to offer. You also saw omni lights and ambient lights in action by adding them to your scene.
- **Three-point lighting:** As an added bonus, you learned how to make 3D scenes look more realistic with this ninja-level lighting technique.

Note: You can find the final project for this chapter under the **projects/final/Breaker** folder.

9 Chapter 9: Geometric Shapes

Chris Language

Getting started

Your game is making significant progress so far. There's a very shiny floor with cameras, lights and even a ball. However, there are still plenty of components to add before it comes close to resembling *Breakout*.

Rest assured, by the end of this chapter you'll have a functional game because the primary focus is adding walls, bricks and a paddle. But you're not going to take the quick and easy way out here — no, you'll create each component from scratch by using geometric shapes directly in the fantastic SceneKit editor.

Note: You can find the starter project for this chapter under the **projects/starter/Breaker** folder.

Geometric shapes

As you know by now, SceneKit comes with a whole bunch of geometric shapes. Here's a nice little grid of all the shapes you'll find under the Object Library:

| | | |
|---|---|---|
|  Plane - Provides a plane geometry. |  Capsule - Provides a capsule geometry. |  Pyramid - Provides a pyramid geometry. |
|  Box - Provides a box geometry. |  Torus - Provides a torus geometry. |  Cylinder - Provides a cylinder geometry. |
|  Sphere - Provides a sphere geometry. |  Floor - Provides an infinite plane with reflection support. |  Cone - Provides a cone geometry. |
|  Geosphere - Provides a geodesic sphere geometry. |  3D Text - Provides 3D Text with extrusion and chamfer support. |  Tube - Provides a tube geometry. |

You've encountered a few of these shapes already and probably found that using them is easy enough. Additionally, those pretty little Xcode icons also do an excellent job of visually representing them.

The main thing you need to remember is that once you've dragged a geometric shape into your scene, you need to adjust the shape node's properties in the Attributes Inspector.

Note: These geometric shapes are also referred to as parametric geometries, because you can control certain aspects of the generated geometric shape via a set of parameters.

Stop for just a second and let your imagination run wild and free. Think of all the marvelous creatures you'll be able to create with these basic geometric shapes!

Believe it or not, this fetching fellow is made of spheres and cones, and was created in Xcode using the SceneKit editor:



Note: If you're feeling brave, go take a closer look at this spider under the **resources/Spider** folder. Double-click the **Spider.scn** file to open it in **Preview** or **Xcode**.

Just look at the handsome little spider with its shiny, little, beady, red eyes staring right at you. Don't you just love these harmless looking critters? :]

For your game, you'll make use of the box shape to create the top and bottom barriers as well as the bricks that'll eventually be smashed to bits. The cylinder shape is what you'll use to make side barriers and the paddle.

Build barriers

In real life, too many barriers can be a bad thing, but in a game, you need plenty of them to make gameplay fun and fair. Think about what would happen in your game once the ball starts moving.

Right now, there's nothing to stop it — not even resistance — so you could gently tap the ball and send it flying off the screen into a parallel universe; it's an outcome that's exciting for the purposes of discussing theoretical physics, but it sure makes for some lousy gameplay.

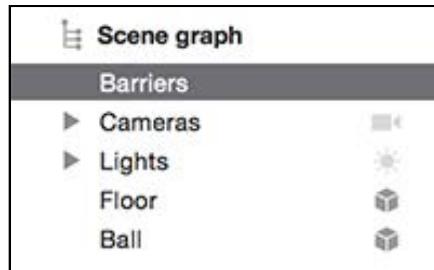
To stop it from flying off into Neverland, you need barriers! :]

Creating a barriers group

You'll make the top and bottom barriers from box nodes.

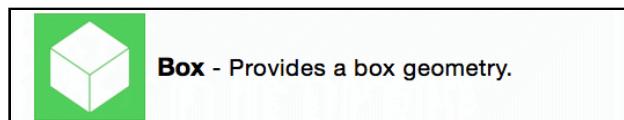
The first step is opening up your project and selecting **Game.scn**. In the SceneKit editor, click the **+** button on the toolbar to create an empty node, and then rename it to **Barriers**.

This will be your group node that contains all the barriers you'll add:

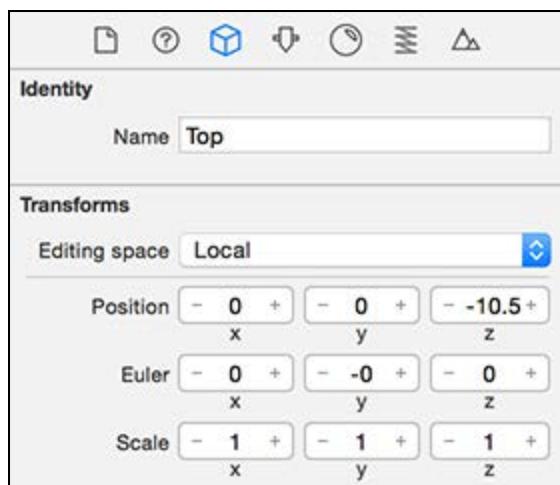


Adding the top barrier

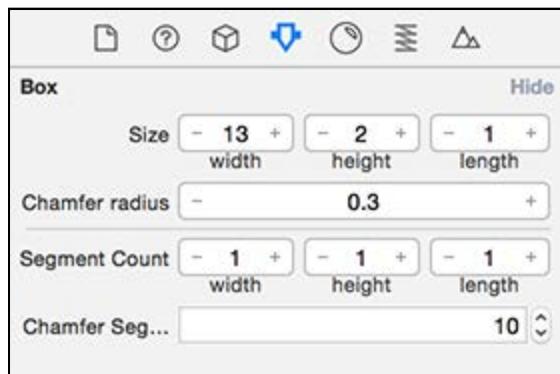
From the Object Library, drag and drop a **Box** into your scene:



Under the scene graph, drag the new box node into your **Barriers** group node. Next, open the Node Inspector, name this node **Top**, and then set its position to (x: 0, y:0, z:-10.5):



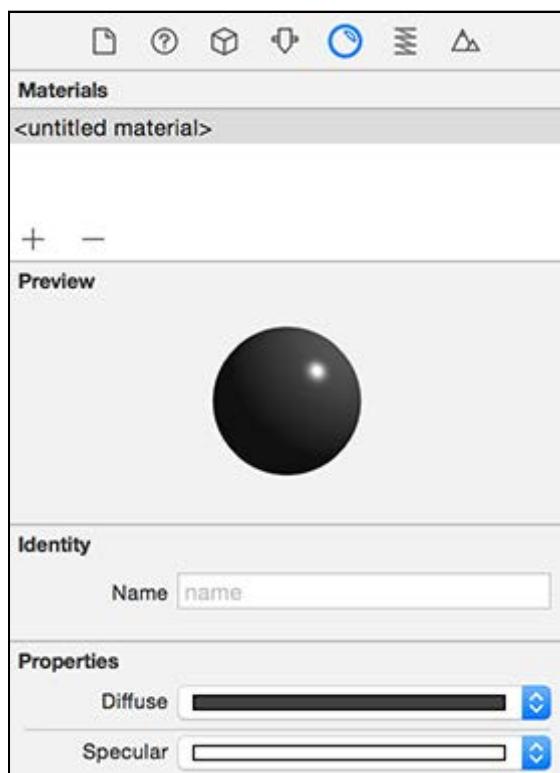
Open the Attributes Inspector and set **Size** to **width:13, height:2, length:1**, and then adjust the **Chamfer radius** to **0.3**:



While the width, height, and length attributes determine the size of the box, the *Chamfer radius* controls edge and corner rounding on the box.

Next, change the color of the barrier so it isn't just a white box. Bring up the Material Inspector, change the **Diffuse** to a dark gray color by setting the **Hex Color #** to **333333**, and change the **Specular** color to **White**.

You should have something like this:



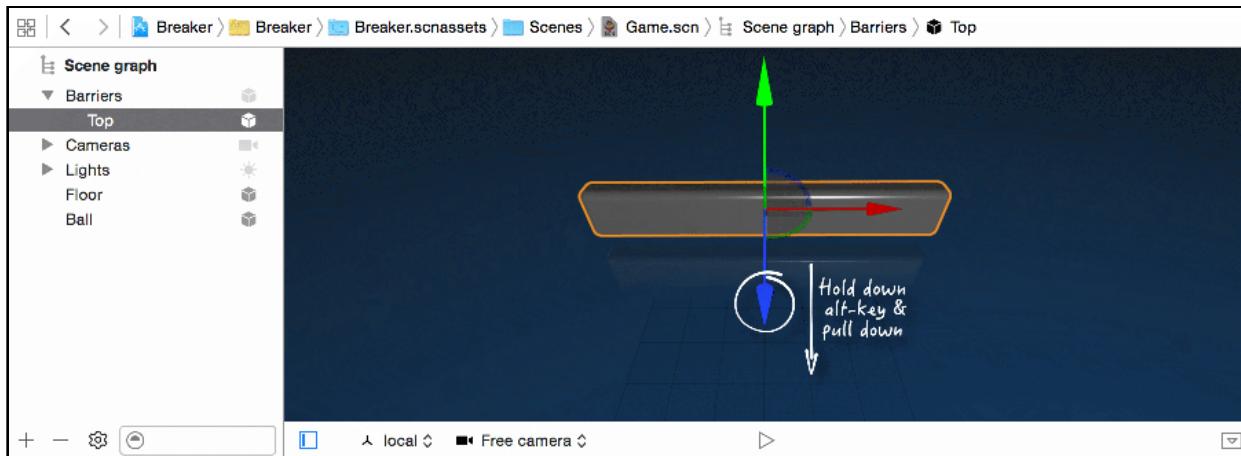
Copying the bottom barrier

The next part involves some trickery. Rather than create another barrier from scratch for the bottom barrier, you'll make a copy of the top barrier and then adjust it.

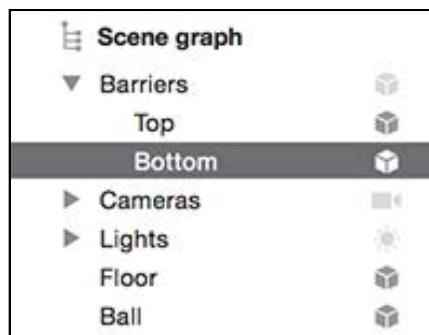
It's a trick of the trade that you should know and love!

To copy nodes in the SceneKit editor, you simply drag from the node you want to copy while pressing the **Option** key.

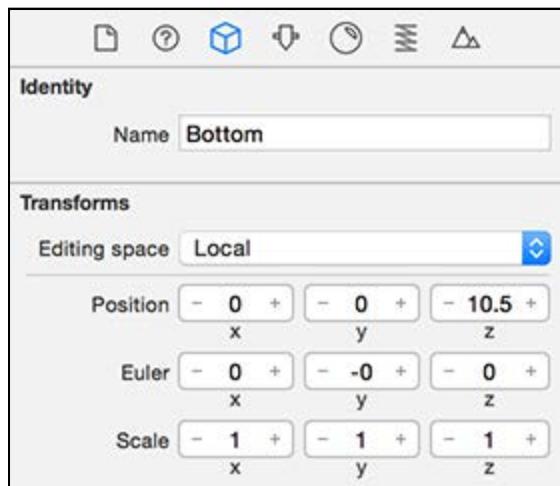
Create a copy of **Top** and select it in the editor. While pressing the **Option** key, **click and drag** the **blue-axis** downwards:



Excellent, now you have a new copy of the **Top** barrier. Fix it up by renaming the copied node to **Bottom** and make it a child of the **Barriers** group.



Reposition that bottom barrier so that it's in the right place. Open the Node Inspector and change **Position** to $(x:0, y:0, z:10.5)$.



The final result should look like this:



Most importantly, take note of the final scene graph tree structure and how the Barriers group contains both the top and bottom barriers.

Before moving on, select the **Attributes Inspector** of the newly copied node, then under the **Geometry Sharing** section, click the **Unshare** button.

When creating copies, the copied node still shares the geometry of the original node. It's a default that's in place to reduce a total amount of draw calls.

Note: At the time of writing this chapter, there appears to be a few strange artifacts with copied geometries with attached physics. To overcome this, make sure to unshare the copied geometry.

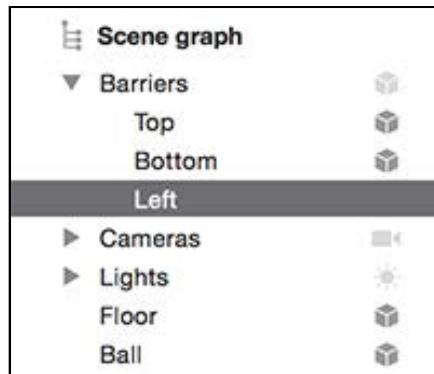
Creating a left barrier group

Now that you have a top and bottom barrier, you need barriers for the left and right sides of the game.

You're going to construct each side barrier with two long cylinders stacked atop one another. Then, you'll group the cylinders for each barrier so you end up with a **Barriers/Left** group and a **Barriers/Right** group.

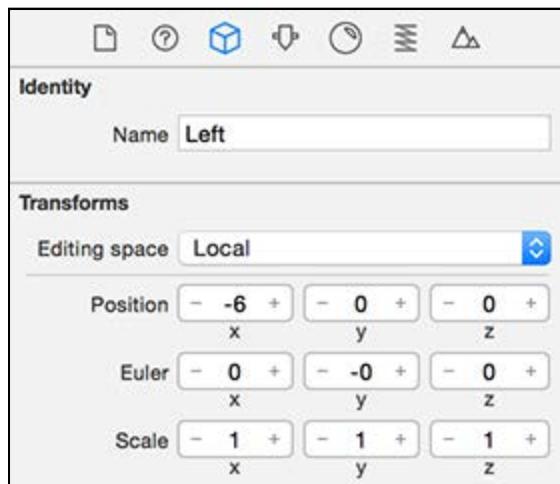
You'll start with building the left barrier.

Highlight your **Barriers** group node and press the **+** button on the toolbar. Rename this new node to **Left**.



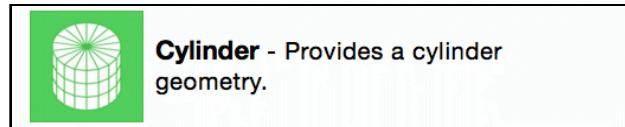
You need to change the position of this group node so that child nodes are in the right place. When you adjust the position of any group node, the positions of all its children are offset.

With the **Barriers/Left** node still selected, select the Node Inspector and change the **Position** to $(x:-6, y:0, z:0)$.

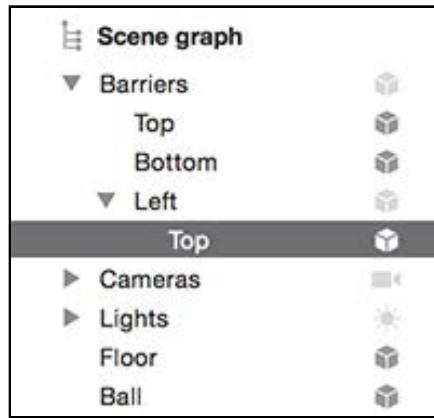


Adding the left-side top barrier

Now, you actually get to create the side barrier! Drag and drop a **Cylinder** from the Object Library into your scene.

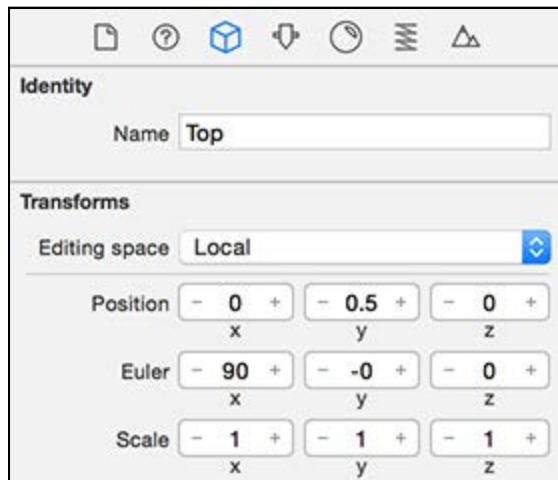


Rename this node to **Top** and fix its position in the scene graph by dragging it under the **Barriers/Left** group node.



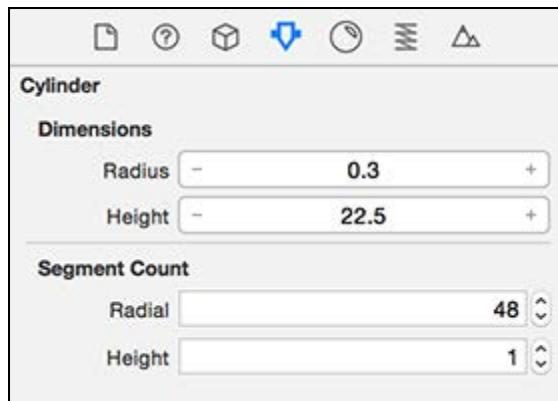
Note: Because a node's position, rotation and scale are always relative to its parent, rearranging the scene graph means the SceneKit editor automatically recalculates the node's properties to maintain the editor's visuals. This can be both a blessing and a curse, so just be aware of this feature.

Place the node in the right location by going to the Node Inspector and setting its **Position** to $(x:0, y:0.5, z:0)$ and **Euler** to $(x:90, y:0, z:0)$:

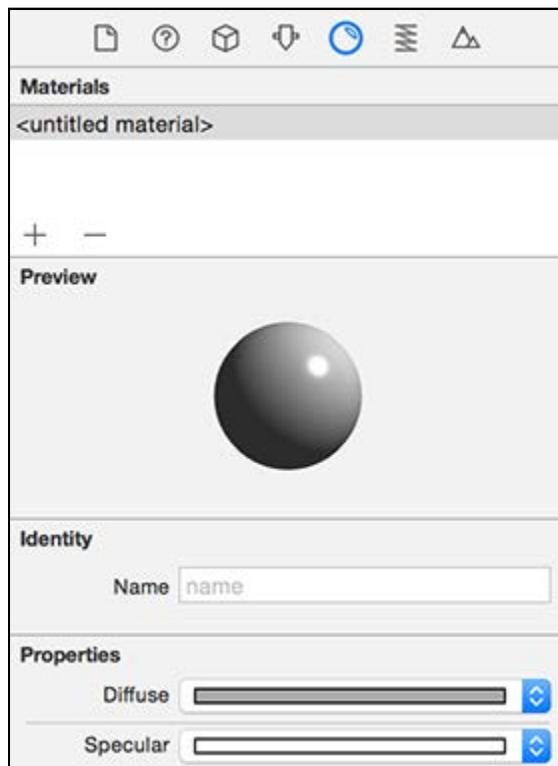


Note: The cylinder node is positioned to the left because it's relative to its parent group node, which has a position of (x:-6, y:0, z:0).

Stretch the cylinder to the correct length and thickness by opening up the Attributes Inspector and setting its **Radius** to **0.3** and **Height** to **22.5**.



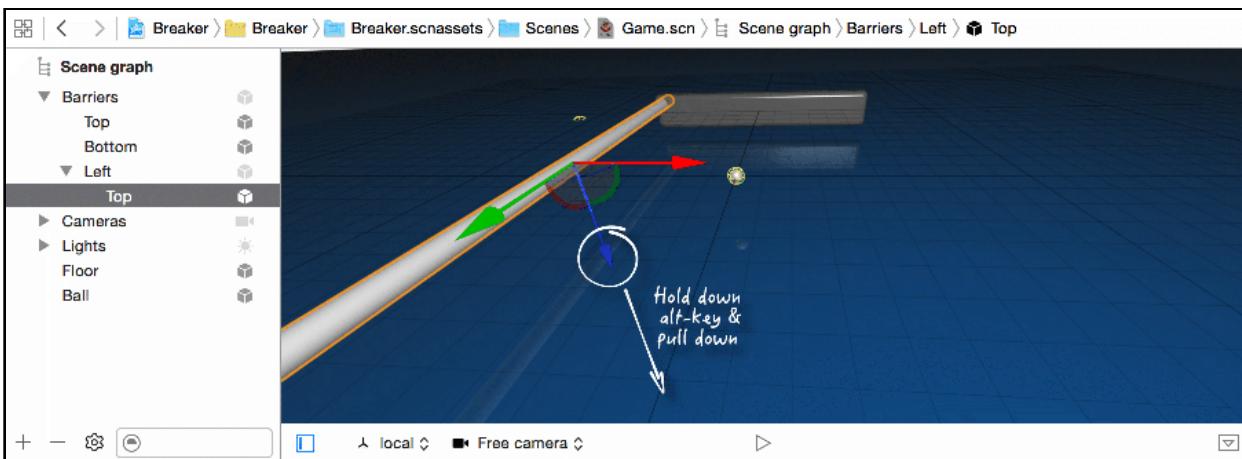
Finally, give the node some color by going to the Material Inspector. Change the **Diffuse** to use a **Hex Color #** of **B3B3B3** and the **Specular** to **White**.



Adding the left-bottom barrier

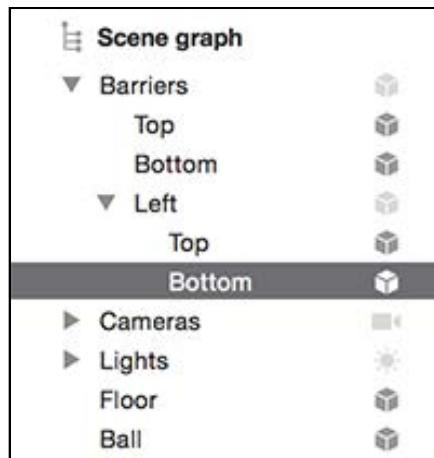
Now that you've sorted out the top-left bar of the barrier, it'll be easy to create the bottom bar from a copy of the top.

Select the **Barrier/Left/Top** node and you should see a little 3D axis on it:

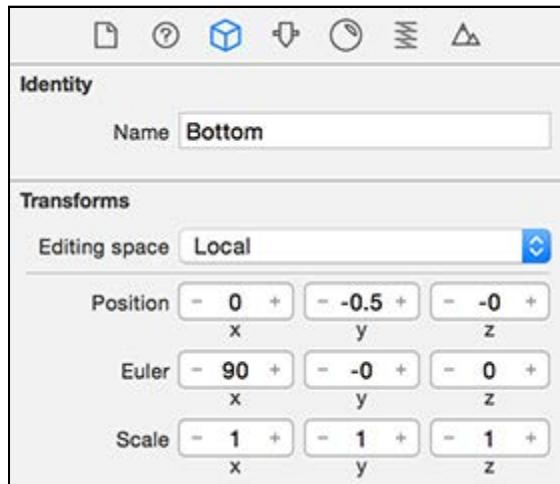


Press and hold the **Option** key, and then **click-drag** the blue axis downwards. Once you're done, just **let go** to create a copy of the bar.

This new copy is probably located at the bottom of the scene graph, but that's not where you want it. Make it a child under the **Barriers/Left** group. Remember to rename it to **Bottom**.



Go into the Node Inspector and adjust the **Position** to $(x:0, y:-0.5, z:0)$.



Your final result should look something like this:



Again, take note of the scene graph and the node tree structure.

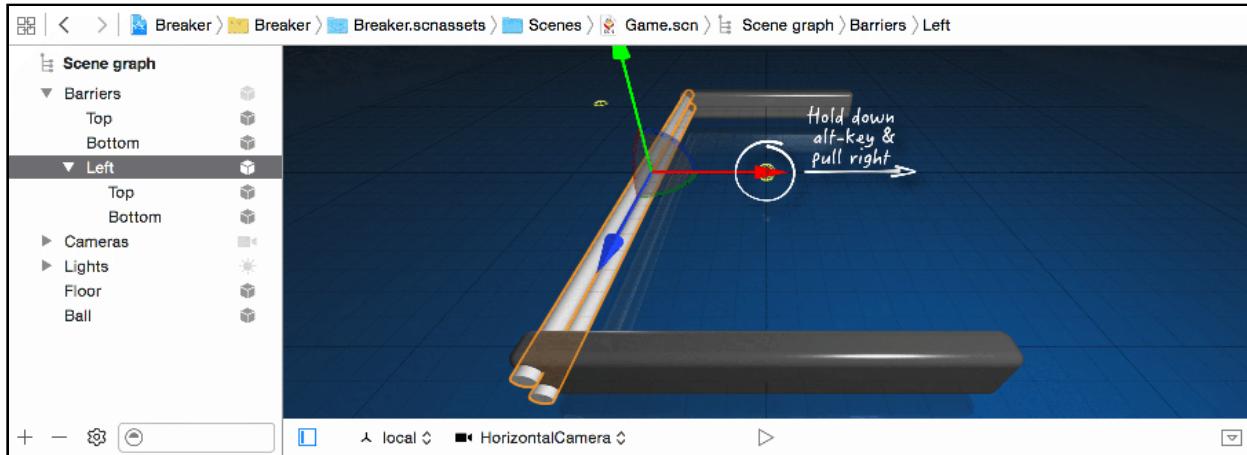
Adding a right-side barrier

Look at that left side barrier in its completed state. Looks pretty nice, right? You did quite a bit of work, and it would be a shame to trudge through all that again.

Good thing you have the ability to copy it all — you've got better things to do than repeat all those steps, like finishing this chapter and having a beer.

Now you'll make a copy of all that fine work, but this time, you'll copy the entire group rather than just a single node.

Select the **Barriers/Left** group in the scene graph:

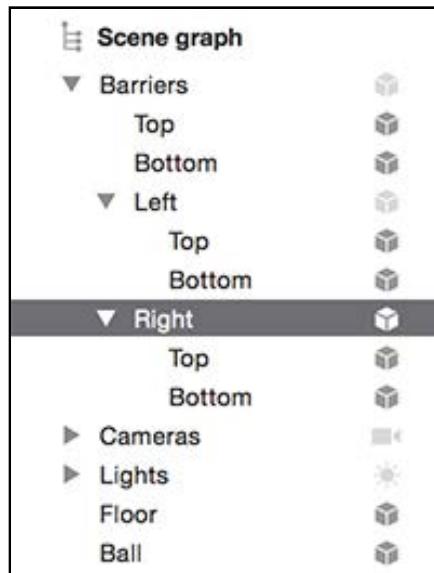


This time, do a snap to move and copy: press **Command** and **Option** then **click-drag** the red axis right. As you drag to the right, you'll notice how the position snaps to the grid layout.

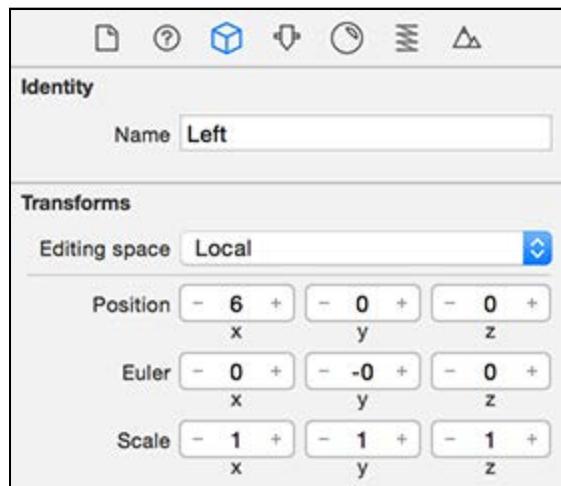
See if you can position it at $(x:6, y:0, z:0)$, and with that, you just created a new copy of the left barrier.

Note: When holding down the Command key while dragging, SceneKit not only snaps the node to the grid, it also snaps to nearby nodes. This useful feature speeds up level design and quite possibly makes life easier.

Rename the group to **Right** and rearrange the scene graph so that the node is a child of the **Barriers** group:



Double-check the position by selecting the Node Inspector and making sure **Position** is set to $(x:6, y:0 z:0)$.

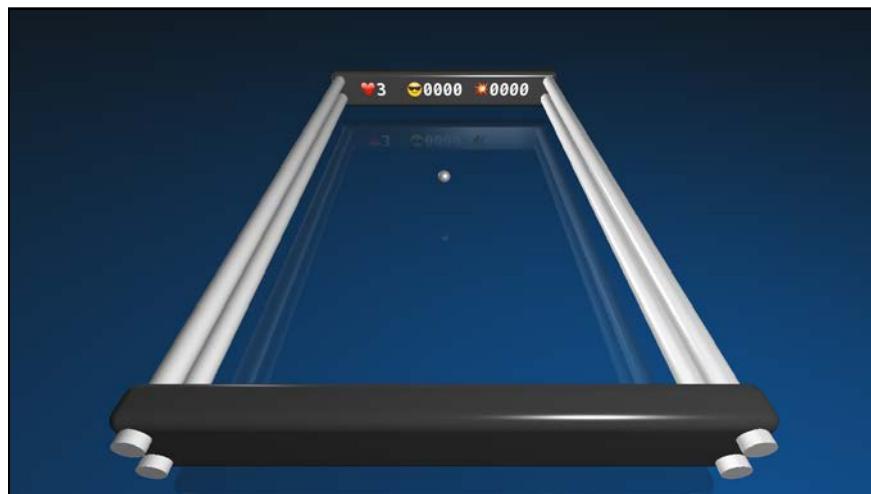


You should end up with the following result:



Great job, you're like a real-life Bob the Builder! :]

Now is the perfect time to do a quick build and run to see those awesome barriers. Your game should look like this:



It's so pretty and shiny! :]

And to think you created all of that by using built-in geometric shapes. Hope you liked the last section, because you're going to play with more shapes in the next one!

Build the paddle

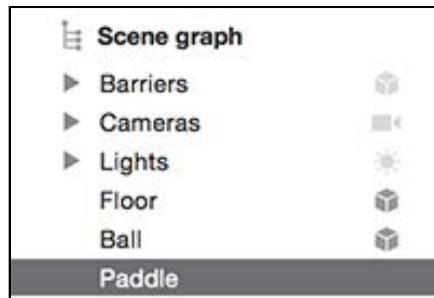
This game is no fun without some means of destruction. Although the paddle is only one part of the weaponry, it's essential, and at this point, missing entirely.

Time to change that.

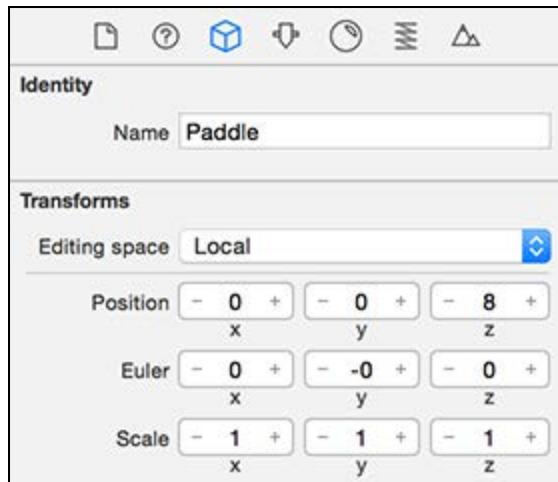
Creating the paddle group

Once again, you'll use cylinder shapes — no surprise there, I hope. The first thing to do is to create an empty node named **Paddle**, which will be your group node for all the paddle's components.

Use the **+** button in the toolbar and rename the node accordingly:



Set the paddle group's position, so that all of its children are placed relative to that group's location. Open the Node Inspector and set **Position** to (x:0, y:0, z:8).

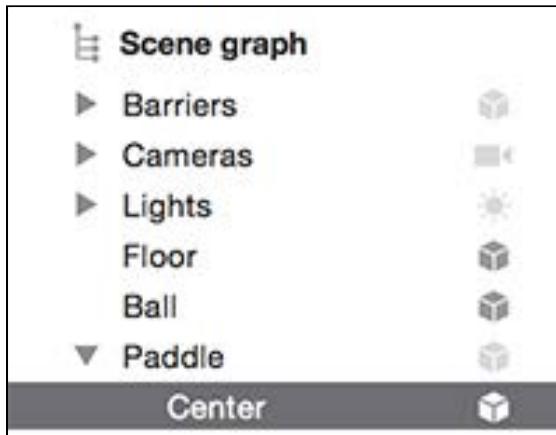


Creating the center of the paddle

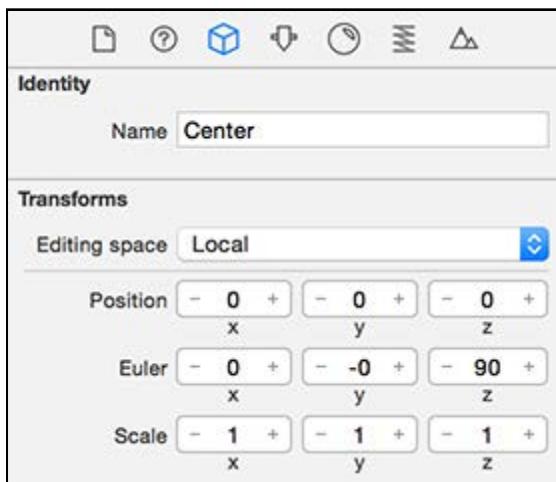
It's time to build the actual paddle. Start by setting up the center part by dragging and dropping a cylinder shape onto your scene.



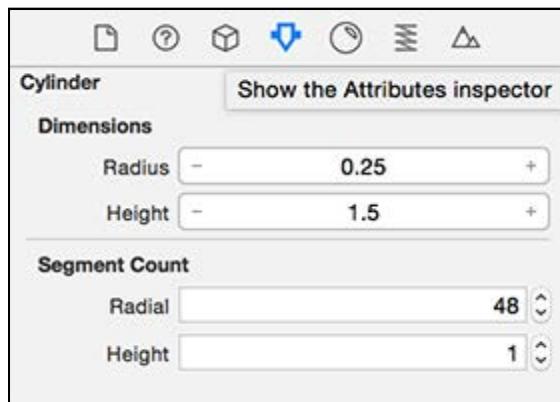
First, rename it to **Center** and sort out its position under the scene graph by dragging it under the **Paddle** group node.



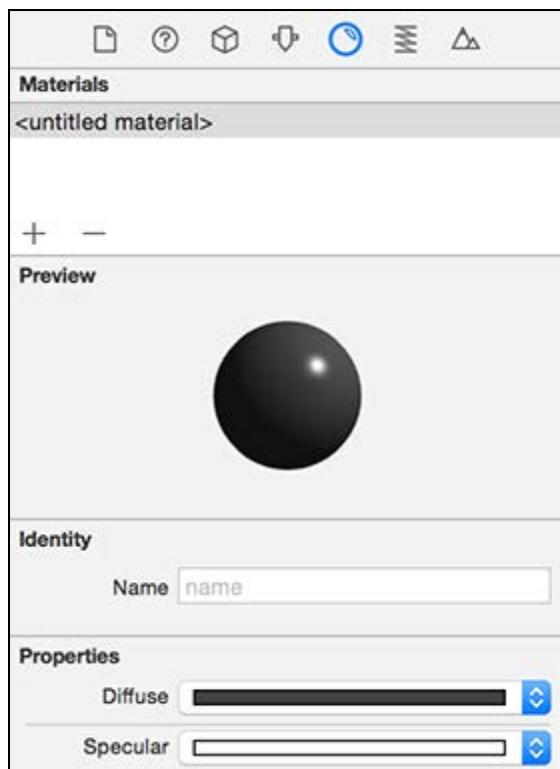
Next, select the Node Inspector and zero out the **x**, **y** and **z** components of the **Position**. Change **Euler** so that it's set to $(x:0, y:0, z:90)$, which will rotate it 90 degrees on the z-axis.



Fix up the size by going to the Attributes Inspector and changing **Radius** to **0.25** and **Height** to **1.5**.

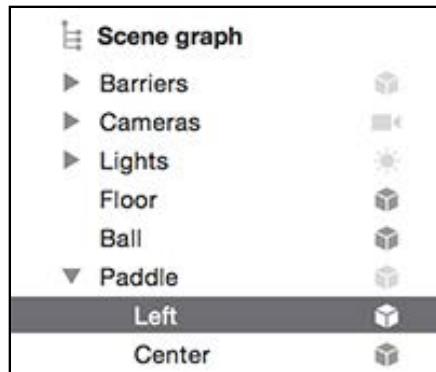


Finally, select the Material Inspector and give this cylinder some color by setting **Diffuse** to a **Hex Color #** of **333333** and **Specular** to **White**.

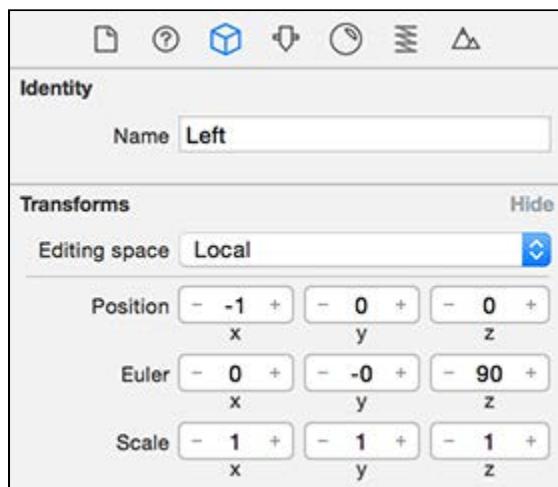


Create the left-edge of the paddle

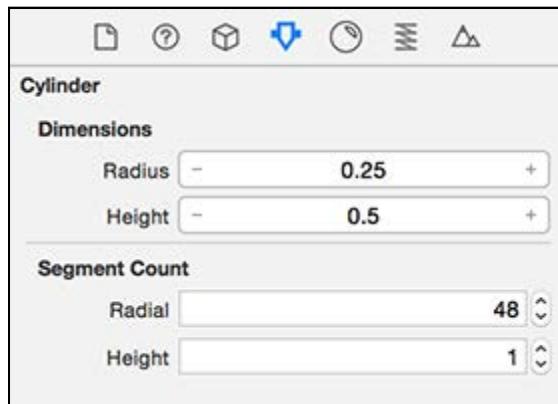
To create the left edge of the paddle, drag and drop a new cylinder shape into your scene. You know the drill by now; name this new node **Left** and drag it under the **Paddle** group node.



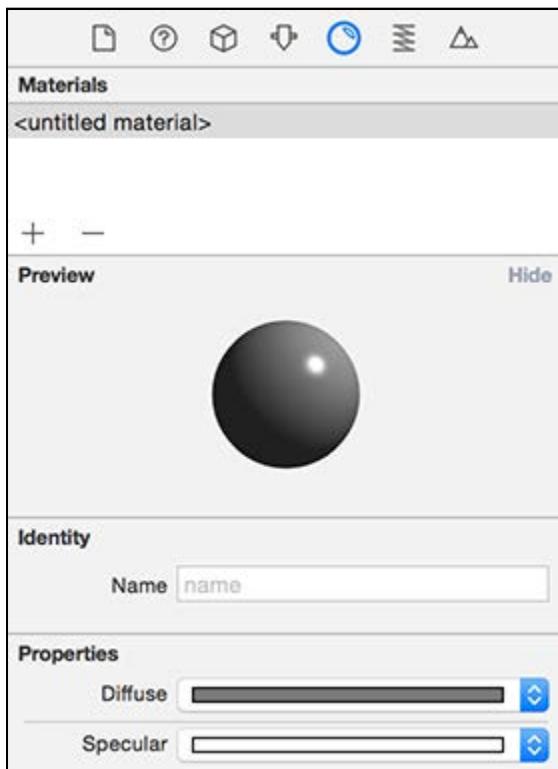
Adjust **Position** to $(x:-1, y:0, z:0)$ and **Euler** to $(x:0, y:0, z:90)$ to rotate it 90 degrees on the z-axis.



Open the Attributes Inspector and set **Radius** to **0.25** and **Height** to **0.5**.



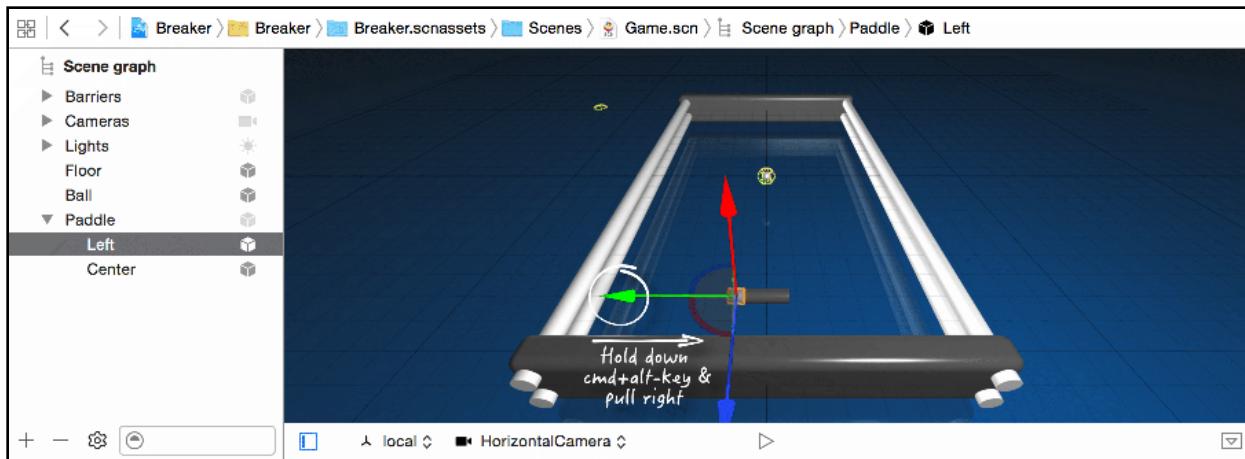
Finally, select the Material Inspector. Give it a **Diffuse** color using **666666** as the **Hex Color #** and a **Specular** color of **White**.



Copying the right-edge of the paddle

Spoiler alert: To create the right-edge, you just start with a copy the left-edge of the paddle.

Highlight the **Paddle/Left** node, hold down **Command** and **Option**, and **drag** the green-axis to the right.



As you move it, take note of how the paddle piece snaps to different parts of the center node. See if you can place it at position (x:1, y:0, z:8). If not, you can always adjust it in the Node Inspector.

Now that you've copied the **Left** edge, rename the node to **Right** and rearrange it in the scene graph, which will update its position to be relative to its parent: (x:1, y:0, z:0).

You should now have the following:



Again, take note of the **Paddle** group and the structure of the nodes within.

Binding to the paddle

So you have a paddle but no way of moving it. That's going to make for some disappointing gameplay!

The next step is to add some code that will bind to the paddle so you'll be able to control it later on.

Open **GameViewController.swift** and add the following property to GameViewController class:

```
var paddleNode: SCNNode!
```

Then bind the paddle in the scene to this property by adding the following line of code to the end of `setupNodes()`:

```
paddleNode =  
    scnScene.rootNode.childNode(withName: "Paddle", recursively: true)!
```

This binds `paddleNode` to the actual paddle group node in `Game.scn`.

Note: You can find the final project, including this most recent section, under the **projects/final/Breaker** folder.

Challenge

Take a look at the checklist for your game so far:

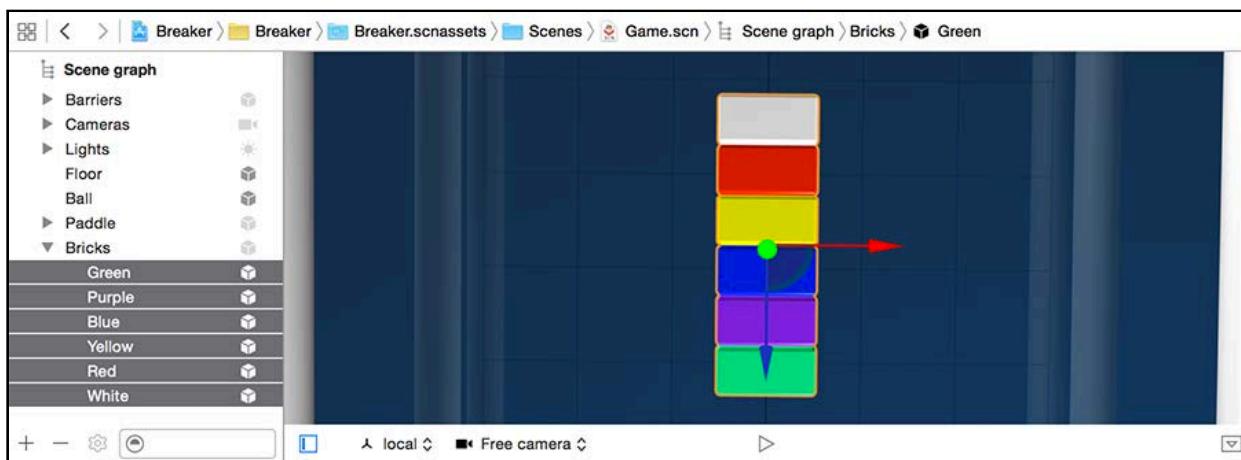
- Barriers ✓
- Paddle ✓
- Ball ✓
- Bricks ✗

You still need something to destroy! :]

This time, I'm leaving the set up as challenge for you. With all the experience and knowledge you've gained so far — such as how to create groups, shapes and how to set their respective properties — try to build the bricks without detailed instructions.

I'll offer up these pointers:

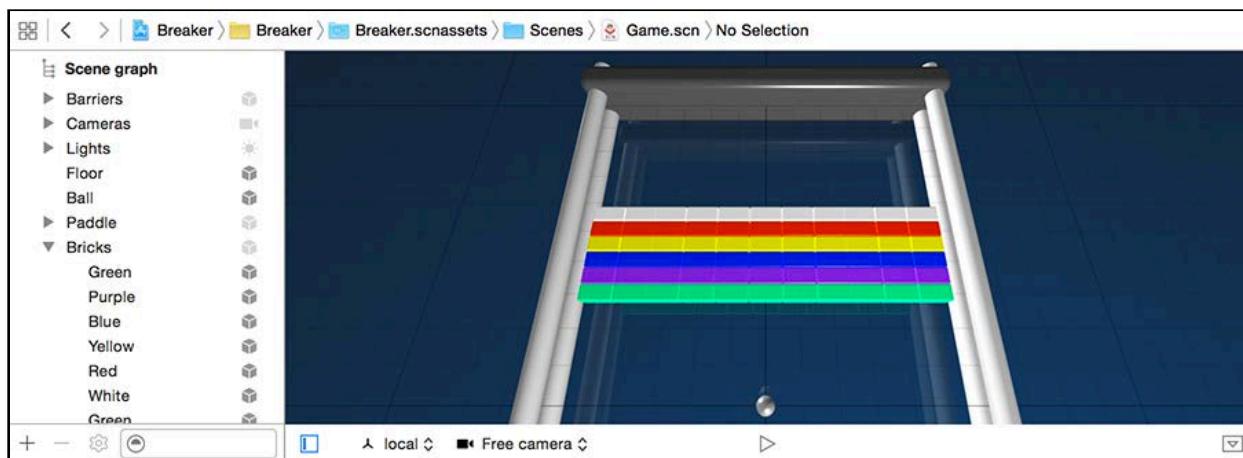
- First create a group node named **Bricks** and place all your bricks under this group.
- Position the **Bricks** group at position (x:0, y:0, z:-3.0).
- For each brick, use a **Box** with a size of **width:1, height:0.5, length: 0.5** and a **Chamfer Radius** of **0.05**.
- Start off by creating a single column of variously colored bricks using white (#FFFFFF), red (#FF0000), yellow (#FFFF00), blue (#0000FF), purple (#8000FF), and green (#00FF80):



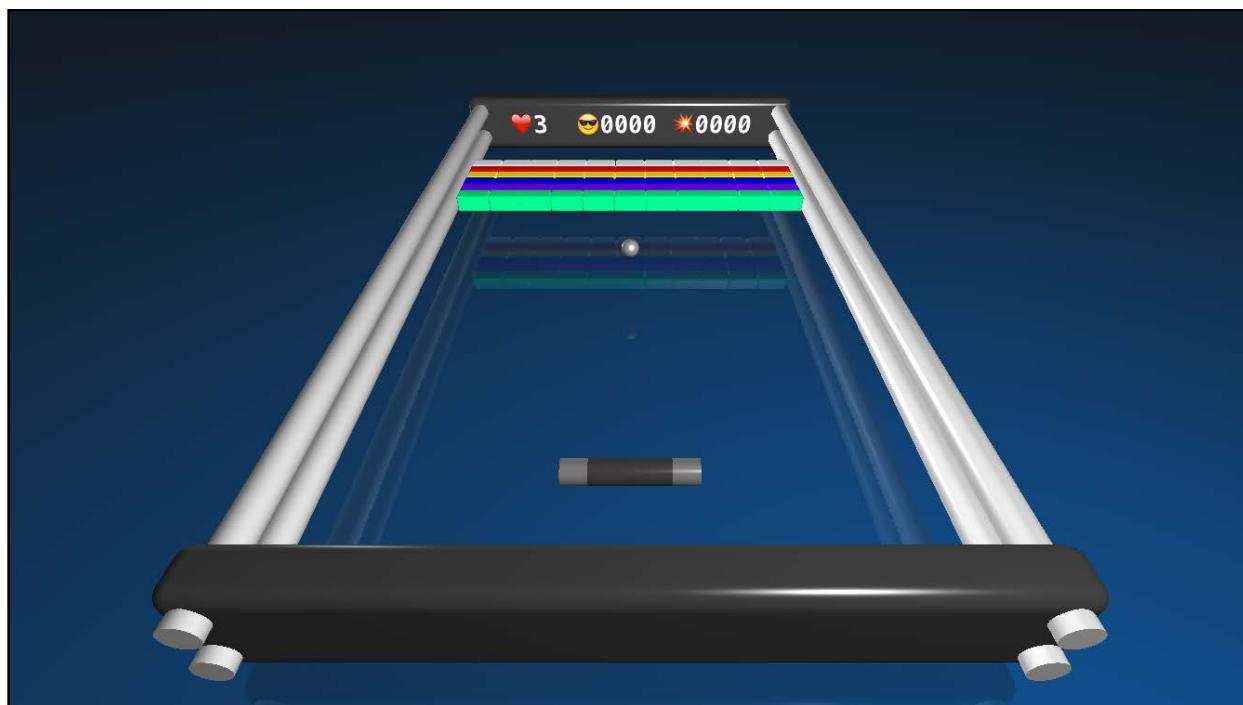
- To help with positioning, I'll tell you that the white brick should be at position (x: 0, y:0, z:-2.5) while the green brick should be at position (x:0, y:0, z:0).
- Name the bricks according to their color.

- Use the copy techniques you've learned. (Press **Option** to copy and **Command** to snap.)
- When making copies, remember to use the **Unshare** button after changing the color on the copies under the Material Inspector, to avoid changing the color of the original.
- Once you have one column, use the copy technique to fill up the area from the left to right barrier.

The final result should look like this:



Build and run to see the complete scene:



Where to go from here?

Fantastic, you just took your game from barely done to mostly ready.

More importantly, you're getting closer to SceneKit Ninja status. Here's a recap of what you learned so far:

- **Geometric shapes:** You built an entire scene out of a few basic geometric shapes.
- **Practical experience:** You built and maintained the scene graph tree structure while keeping all the nodes neat and organized. You learned how to save yourself countless hours by copying nodes. You also worked with lots of objects together in one scene, and you survived the ordeal! :]

Note: You can find the complete project for this chapter, including the challenge section, under the **projects/challenge/Breaker** folder.

Chapter 10: Basic Collision Detection

Chris Language

Getting started

Your game is not quite done yet; there are still a few things standing between you and being a legend in the gaming world:

1. **Physics:** Without any physics for basic collision detection, the ball has no concept of barriers, bricks and paddles. Adding physics to the mix lets that ball detect and collide with objects in its path as it bounces about.
2. **A way to move the paddle around:** Without control, you've got no game! You'll add a simple touch control to solve this and learn how to make the camera track the paddle as it moves around, giving the game a very 3D feel. :]

By the time you've found the end of this chapter, most loose ends will be neatly tied and you'll be the proud designer of another playable, fun game.

Note: You'll find the starter project for this chapter under the **projects/starter/Breaker** folder, it continues with the previous chapter's challenge completed.

Add physics

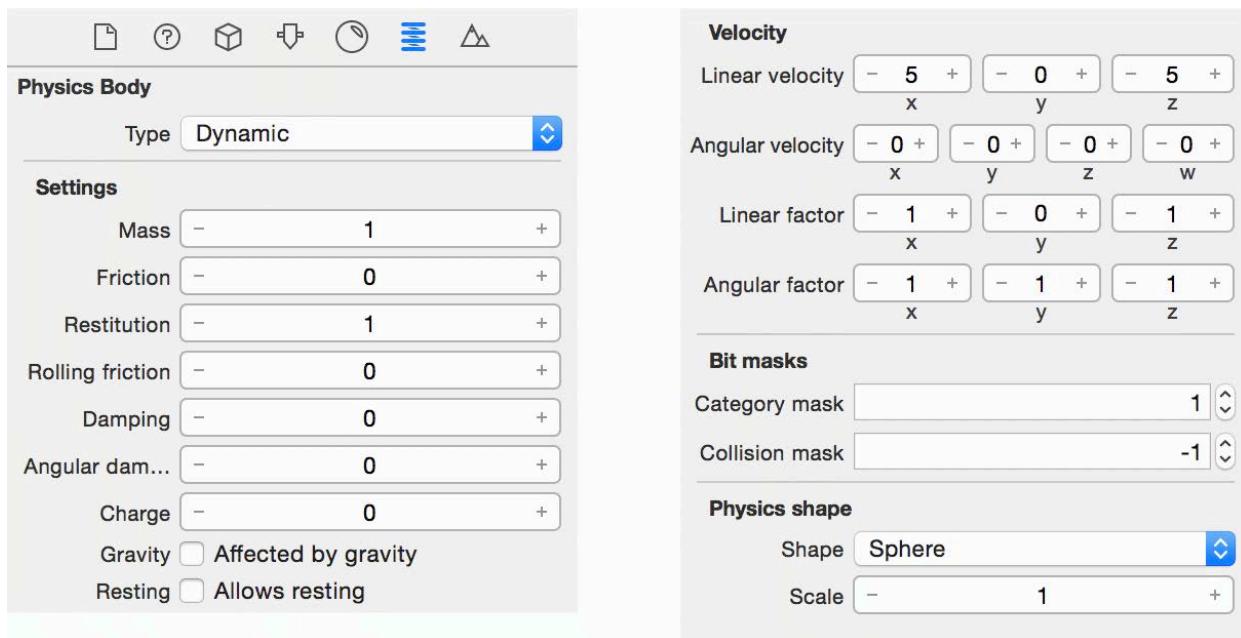
The first step is to add physics for basic collision detection with the game: for the ball, barriers, bricks and paddle. You'll start with the ball.

Adding physics for the ball

A ball without bounce is like a kitten without attitude, so you need to add some physics to get that ball to behave as a ball should.

Open **Game.scn** and select the **Ball**. This time, open the **Physics Inspector**, which is denoted by the little spring icon, and is located to the right of the Material Inspector.

By default, any nodes you add to the scene will be devoid of physics, but adjusting the **Type** of the **Physics Body** to **Dynamic** will bring up a list of settings.



Time to go through each category's properties and how you should set them up:

- **Physics Body:** Determines the type of body. Set the ball's **Type** to a **Dynamic** body, which means that the SceneKit physics engine will take full control over the ball's movement.
- **Settings:** Allows you to fine tune the behavior of the physics body. For the ball, set both **Mass** and **Restitution** to **1**. Zero out all the other physics settings, and uncheck both **Affected by gravity** and **Allows resting**. This will set the ball to bounce freely without constraint from gravity.

- **Velocity:** Affects the speed and direction of the physics body. Give the ball a **Linear velocity** of (x:5, y:0, z:5). This setting gives the ball an initial force once the scene starts running. Set the **Linear factor** to (x:1, y:0, z:1). It zeroes out any physics forces that might be applied to the ball in the y-axis, thus keeping the ball fixed in the same y-position no matter what. This way the ball will never go flying off the playfield.
- **Bit Masks:** Used to set up collisions later. Set the **Category mask** to 1. This assigns a bit mask value of 1 to the ball. This mask is used to create collision groups and uniquely identify certain nodes. The physics engine then uses this information to apply collision calculations to determine which objects collide with one another. This is a bitwise mask; you'll learn more about this in the section "Detecting contact with bitmasks" later in this chapter.
- **Physics Shape:** Defines the actual shape of the physics body that will be used during collision detections. Set the **Shape** to **Sphere** to mimic the visual geometry.

Note: At the time of writing this chapter, there appears to be a few bugs in the SceneKit editor relating to physics. Sometimes, when you re-position a node with attached physics, the physics wireframe gets left behind due to some refresh issue. If you run into this problem, the best way around it is to make sure you save your work and restart Xcode.

Adding physics for the barriers

Your barriers are already there and functional, but they're rather static and don't react to physics yet. This section is all about putting some bounce in those bumpers!

To configure the physics properties for the barriers, you're going to make use of a very cool SceneKit feature. Instead of setting up each object individually, you can select multiple nodes and configure them all in one fell swoop.

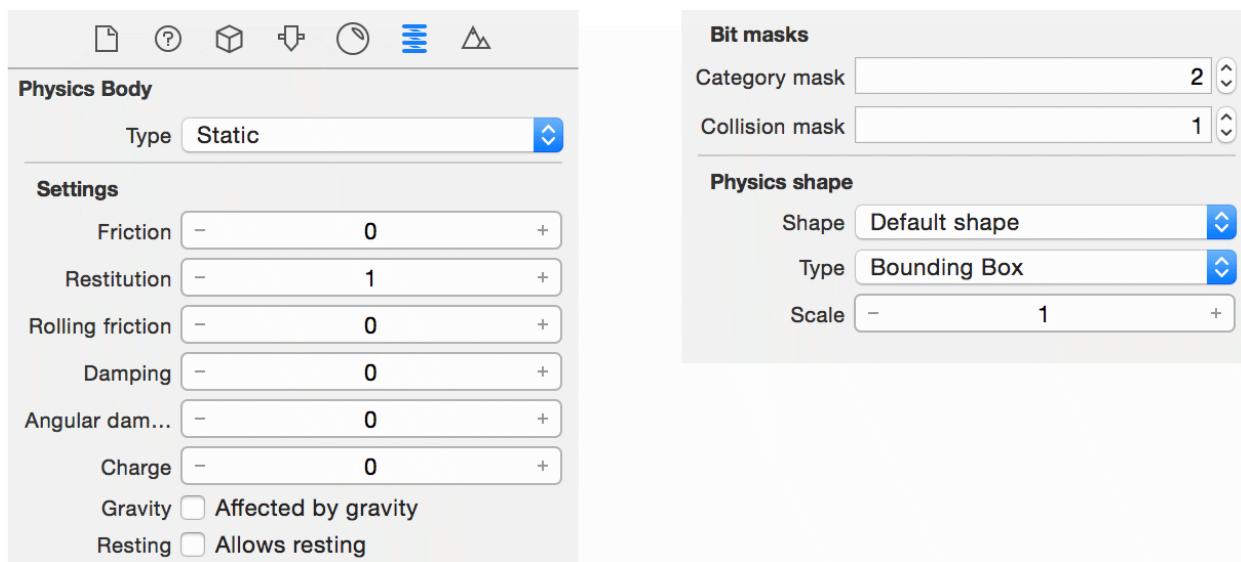
To select all four parts of the barrier at once, there are two different techniques:

1. Pressing **Command** while clicking each node individually in the scene graph, allowing you to select the desired nodes one by one.
2. Select a range of nodes in the scene graph at once. Select the **Top** node first, press and hold **Shift**, and then click the **Right** group node; it will also highlight everything between the two nodes you select.

Whichever method you choose, your goal is to select every part of the barrier:



Now, with all the parts still highlighted, open the Physics Inspector. Under the **Physics Body** section, change the **Type** to **Static**, and then this list of settings will show up:

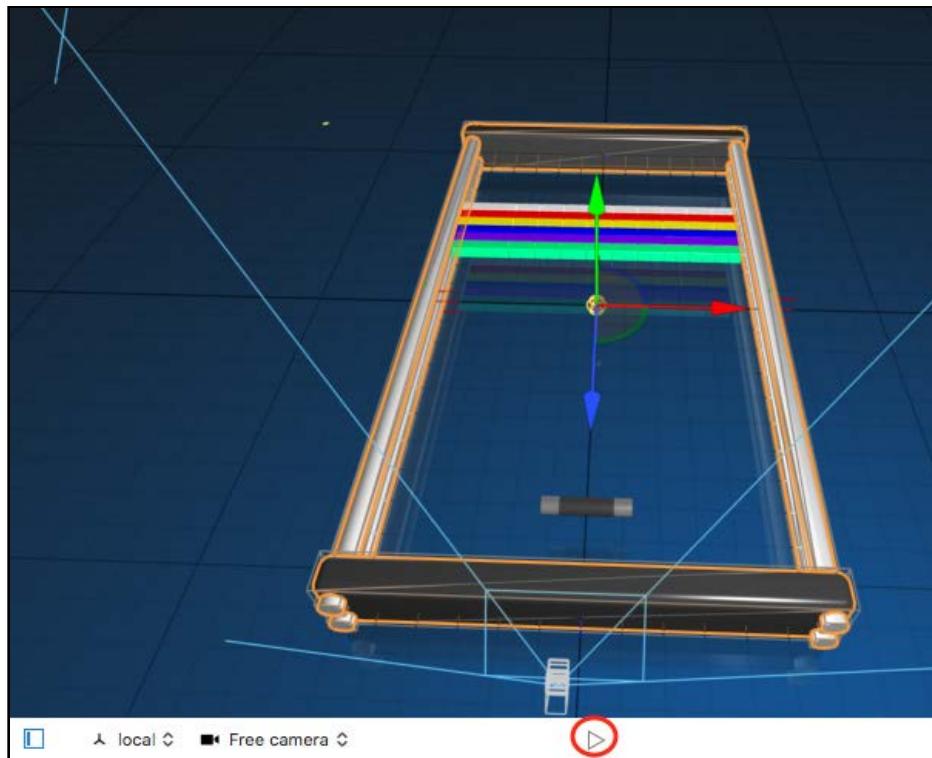


It's broken out into lists, and here's what to do with each part and why you're choosing each setting:

- **Physics Body:** For the **Type**, set it as a **Static** body so the barriers will not move, nor will they move around with any actions.
- **Settings:** Zero out all the settings and set **Restitution** to 1, making it so that no energy is lost when collisions happen. Uncheck both checkboxes so the barriers aren't influenced by gravity either.
- **Bit masks:** Set **Category mask** to 2 and **Collision mask** to 1. This gives the barriers a category bit mask of 2 and sets them to collide with objects that have a category bit mask of 1 — the same category bit mask you gave to the ball.

- **Physics Shape:** Set **Shape** to **Default shape** and **Type** to **Bounding Box**. Because the two side barriers are nodes with children, this option is more fitting because a bounding box creates a boundary around all the child nodes within the group instead of each object individually. If you look at the scene editor, you'll find that there's a red wireframe that shows the boundary the physics body will take.

Do something fun here and press the little play button on the toolbar:



You should see the ball bounce like crazy off all four barriers. Sweet! :]

Here you have a quick simulation of your game's physics. Talk about a handy tool! You're testing out your physics without constantly building and running. Stop the animation by pressing the stop button on the toolbar.



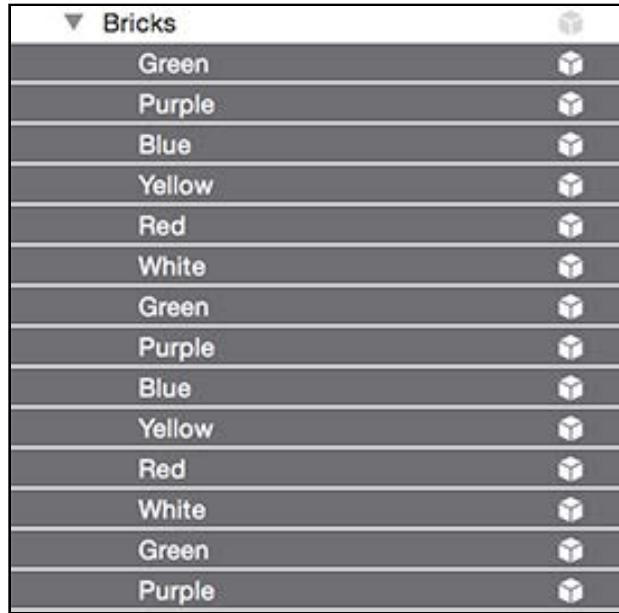
Adding physics for the bricks

Right now each brick is just another boring brick in a wall. If you don't give them some physics, how can you have any collisions?

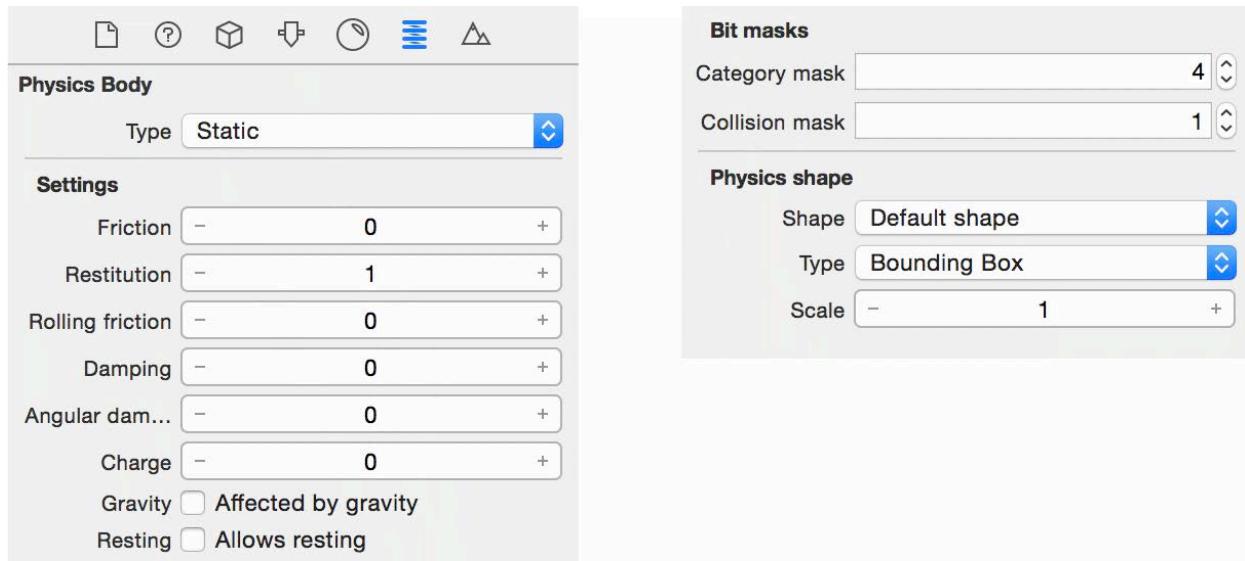
To configure the physics properties for the bricks, select all the bricks under the scene graph tree.

Use the Shift key technique to select a range by pressing and holding **Shift**, clicking the first brick then selecting the last brick.

This is how it should look when you've selected all the bricks:



Select the Physics Inspector and change the bricks to be a **Static** body.



Before closing out the window, set the following settings for the bricks:

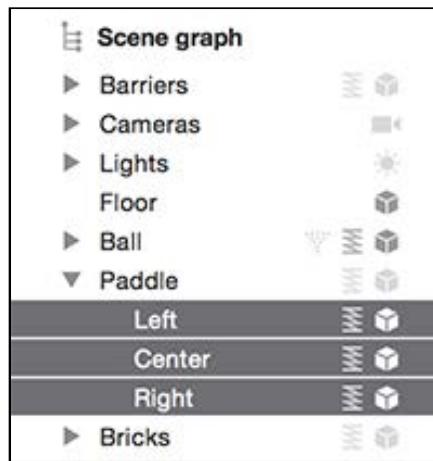
- **Physics Body:** The bricks are not going to move around and you won't move them with actions, so set the **Type** to **Static**.
- **Settings:** Like you did with the barriers, zero out all the settings and set **Restitution** to 1. Again, make sure to uncheck the two checkboxes.
- **Bit masks:** This time, set the **Category mask** to 4 and the **Collision mask** to 1. This gives the bricks a category bit mask of 4, and makes it so they will collide with objects that have a category mask of 1 — critical because the ball needs to be able to smash bricks.

Note that since this is a bitwise bitmask, you don't just increment the value to three. 4 in decimal is 100 in binary, which represents the third bit from the right. This is explained more in the "Detecting contact with bitmasks" section later in this chapter.

- **Physics Shape:** Set **Shape** to **Default shape** and **Type** to **Bounding Box**.

Adding physics for the paddle

Now for the last piece of the physics puzzle: the paddle. To configure, start by selecting all the child nodes under the **Paddle** group. You'll configure all three nodes together:



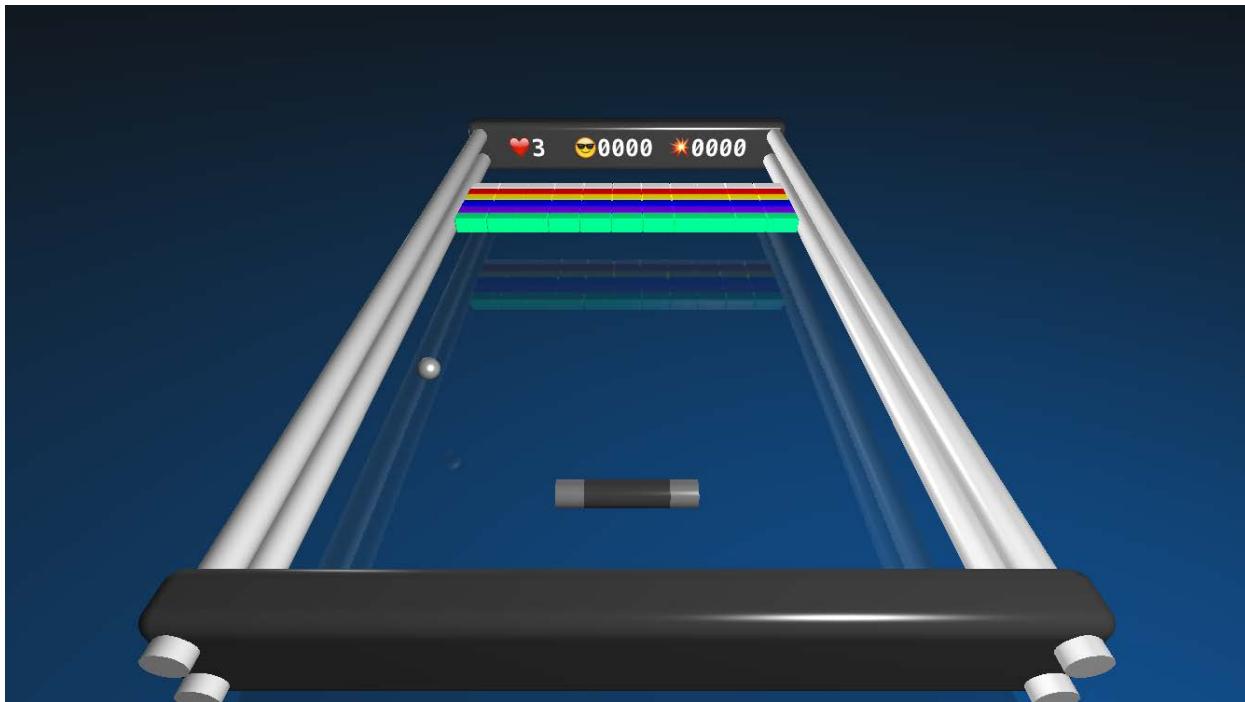
Open the Physics Inspector and adjust the **Type** to **Kinematic**. Take a look at the list of properties you'll need to set for the paddle:

The image shows two side-by-side screenshots of the Physics Inspector. The left screenshot shows the 'Physics Body' tab. It has a dropdown menu for 'Type' which is set to 'Kinematic'. Below this are sections for 'Settings' containing sliders for Friction (0), Restitution (1), Rolling friction (0), Damping (0), Angular damping (0), Charge (0), and checkboxes for 'Affected by gravity' (unchecked) and 'Allows resting' (unchecked). The right screenshot shows the 'Bit masks' tab. It includes fields for 'Category mask' (set to 8) and 'Collision mask' (set to 1). The 'Physics shape' section contains dropdown menus for 'Shape' (set to 'Default shape') and 'Type' (set to 'Bounding Box'), and a slider for 'Scale' (set to 1).

- **Physics Body:** Since the paddle must move around, you set the **Type** to **Kinematic**. This lets the physics engine know that you'll take control of the object's movement, but still allows these nodes to participate in collisions.

- **Settings:** Once again, zero out all the settings and set **R restitution** to 1. Make sure to uncheck the checkboxes.
- **Bit masks:** Set the **Category mask** to 8 and the **Collision mask** to 1. This gives the paddle a category bit mask of 8 and sets it to collide with the ball, which by now you know has a category bit mask of 1.
- **Physics Shape:** Set **Shape** to **Default shape** and **Type** to **Bounding Box**.

At this point, build and run.



The ball should bounce like crazy off the barriers, bricks and even the paddle.

Note: If performance is slow on the simulator, be sure to run on a physical device instead. SceneKit apps will often run far slower on the simulator than how it will run on an actual physical device.

Handling collision detection

You're getting closer to applying gameplay logic, but you can't tap into the moments when collisions happen until you've gone through the steps to set up the physics.

So how exactly does one tap into these so-called moments? Meet the **SCNPhysicsContactDelegate** protocol! This protocol defines the following methods that you can override to respond to collision events:

- **physicsWorld(_:didBegin:)**: This method gets called once two physics bodies come into contact with each other.
- **physicsWorld(_:didUpdate:)**: This method gets triggered after contact has begun and provides additional information about an ongoing collision between two bodies.
- **physicsWorld(_:didEnd:)**: This method gets called once contact between bodies comes to an end.

Note: Each one of these methods will be passed a **SCNPhysicsContact** object that contains the two nodes that are in contact with one another.

Implementing the contact protocol methods

Before you start implementing the methods in **SCNPhysicsContactDelegate**, you need to set up a helper property to use a bit later.

Open **GameViewController.swift** and add this new property to **GameViewController**:

```
var lastContactNode: SCNNNode!
```

You'll use this property to keep track of the last node with which the ball made contact.

It's important because there's a little side effect you need to overcome. See, the physics engine will continuously report a collision with the same node if two nodes slide against each other. You don't want that here; at this point you only care about the initial collision.

Another reason for the property is that although they are still colliding, in *Breaker*, the ball cannot make contact with the same node until it hits another node, so you need it to make sure that you only handle the collision once.

Now that you have this helper set up, it's time to implement the protocol so that you can add gameplay logic for collisions.

Add the following extension to the bottom of **GameViewController.swift**:

```
// 1
extension GameViewController: SCNPhysicsContactDelegate {
// 2
    func physicsWorld(_ world: SCNPhysicsWorld,
                      didBegin contact: SCNPhysicsContact) {
// 3
        var contactNode: SCNNNode!
        if contact.nodeA.name == "Ball" {
            contactNode = contact.nodeB
        } else {
            contactNode = contact.nodeA
        }
// 4
        if lastContactNode != nil &&
           lastContactNode == contactNode {
            return
        }
        lastContactNode = contactNode
    }
}
```

Take a closer look at this chunk of code:

1. This extends GameViewController to implement SCNPhysicsContactDelegate. Pro tip: Using extensions to add protocol conformance is a good way to organize your code.
2. The method you're implementing inside the protocol is `physicsWorld(_:didBegin:)`, and it's called when two physics bodies you're interested in start making contact with each other. By default, collisions don't trigger this method, so you'll opt in to it shortly.
3. When this method is called, a SCNPhysicsContact is passed to you as a parameter, so you can determine the two nodes that are making contact by accessing `contact.nodeA` and `contact.nodeB`. With *Breaker*, you know that one of them will be the ball and the other will be a barrier, brick or paddle. This bit of code applies a nifty little trick to filter out which node is which, and once done, `contactNode` ends up being the one the ball made contact with.
4. This last bit will also prevent the ball from making contact with the same node more than once per interaction by using `lastContactNode`, which you set up earlier.

Detecting contact with bitmasks

Earlier when you set up the physics properties for the different elements for your game, you put in various numbers for the **Category bitmask**. The values you used were actually numbers chosen to represent a certain value in binary representation.

Take a look at the categories you used for *Breaker* and you should notice a pattern:

```

Ball:      1 (Decimal) = 00000001 (Binary)
Barrier:   2 (Decimal) = 00000010 (Binary)
Brick:     4 (Decimal) = 00000100 (Binary)
Paddle:    8 (Decimal) = 00001000 (Binary)

```

The position of the bits in binary representation is used to store a 1 or 0 when dealing with bitmasks.

Define a new enum for the above list by adding the following code to the top of GameViewController, just after the imports section but before the class definition:

```

enum ColliderType: Int {
    case ball      = 0b0001
    case barrier   = 0b0010
    case brick     = 0b0100
    case paddle    = 0b1000
}

```

Now, instead of remembering numbers, you can use `ColliderType.ball.rawValue` as bit mask value for the ball.

To see this in action when dealing with collisions, add the following line of code to the end of `setupNodes()`:

```

ballNode.physicsBody?.contactTestBitMask =
    ColliderType.barrier.rawValue |
    ColliderType.brick.rawValue |
    ColliderType.paddle.rawValue

```

As mentioned previously, the physics engine doesn't call `physicsWorld(_:didBegin:)` for every collision by default. To start getting these calls, you need to set the `contactTestBitMask` of a physics body to tell the physics engine that you're interested in notification when collisions happen.

In the line above, you let the physics engine know that you want to call the protocol method whenever the ball collides with nodes that have a category bit mask of either 2, 4, or 8 — respectively, these represent a barrier, brick or paddle.

Note: You can also define more complex scenarios by making a body part of multiple categories.

Now that you have defined when the protocol method gets called, it's time to jazz things up with more functionality based on the nodes with which your ball will collide.

Add the following lines of code to the bottom of `physicsWorld(_:didBegin:)`:

```
// 1
if contactNode.physicsBody?.categoryBitMask ==
ColliderType.barrier.rawValue {
    if contactNode.name == "Bottom" {
        game.lives -= 1
        if game.lives == 0 {
            game.saveState()
            game.reset()
        }
    }
}
// 2
if contactNode.physicsBody?.categoryBitMask ==
ColliderType.brick.rawValue {
    game.score += 1
    contactNode.isHidden = true
    contactNode.runAction(
        SCNAction.waitForDurationThenRunBlock(duration: 120) {
            (node:SCNNode!) -> Void in
            node.isHidden = false
        })
}
// 3
if contactNode.physicsBody?.categoryBitMask ==
ColliderType.paddle.rawValue {
    if contactNode.name == "Left" {
        ballNode.physicsBody!.velocity.xzAngle -=
            (convertToRadians(angle: 20))
    }
    if contactNode.name == "Right" {
        ballNode.physicsBody!.velocity.xzAngle +=
            (convertToRadians(angle: 20))
    }
}
// 4
ballNode.physicsBody?.velocity.length = 5.0
```

Take a closer look at the code:

1. Earlier in the method, you added a way for the node that makes contact with the ball to become a contactNode. This section checks whether the ball is making contact with a barrier by looking at the categoryBitMask of contactNode. Then, you check the name of the node to find out which barrier was hit — remember, you named all your nodes when creating them earlier in the SceneKit editor.

With the barrier identifiable, you can tell when the ball hits the bottom. It matters because there's a penalty involved: you reduce the number of lives and when there are zero lives left, you save the high score and reset the game. Game over!

2. This checks whether the ball is making contact with a brick using the same technique as above. The rest of the code lets the brick disappear for 120 seconds then makes it reappear from the dead like a zombie. Yeah! Unlike a traditional breakout game where the bricks dissapear forever, this approach basically simplifies the game a bit by making it endless in nature. Oh yes, contact with the brick increases the score as well.
3. The last type of node to check is the paddle, so this checks which part of the paddle the ball hits. If it strikes the center of the paddle, the physics engine takes over and deflects the ball appropriately. However if it hits the left or right side, it adjusts the velocity of the ball by 20 degrees. You do this by first using a helper function from Game Utils to convert the angle from degrees to radians, and then you use this value to adjust the `xzAngle` of the ball's velocity. This added functionality gives the player a little variation in the ball's movement to keep things interesting.
4. Once all checks are performed, this last step brings some control over the physics behavior, forcing the ball to a constant speed of five. Remember that you're dealing with physics simulation, which is somewhat unpredictable, so bringing in adjustments like these gives the player more control of the game.

Setting up the contact delegate

Now that you have all the pieces ready, the last thing you need to do is hook up the delegate.

Add the following line of code to bottom of `setupScene()`:

```
scnScene.physicsWorld.contactDelegate = self
```

In order to be notified of contact events, you need to tell the physics engine that your class will now take responsibility for handling the protocol methods. You do that by setting the physics world's `contactDelegate` to `self`.

Build and run, and you should see the ball bouncing around the screen, destroying bricks along the way!



Adding touch controls

What fun is a game without any controls? Not much! In this section, you're going to add some simple touch controls so the player can slide the paddle to and fro.

Start by adding the following properties to GameViewController:

```
var touchX: CGFloat = 0  
var paddleX: Float = 0
```

These properties simply store the touch's initial x-position and the paddle's x-position.

Next, add the following method to GameViewController:

```
override func touchesBegan(_ touches: Set<UITouch>, with event: UIEvent?)  
{  
    for touch in touches {  
        let location = touch.location(in: scnView)  
        touchX = location.x  
        paddleX = paddleNode.position.x  
    }  
}
```

Here, you override `touchesBegan(_:_with:)` which gets called every time the user touches the screen. As soon as a touch starts, this code simply stores the touch and paddle's x-position.

Now, you can finally get the paddle moving by adding the following method to GameViewController:

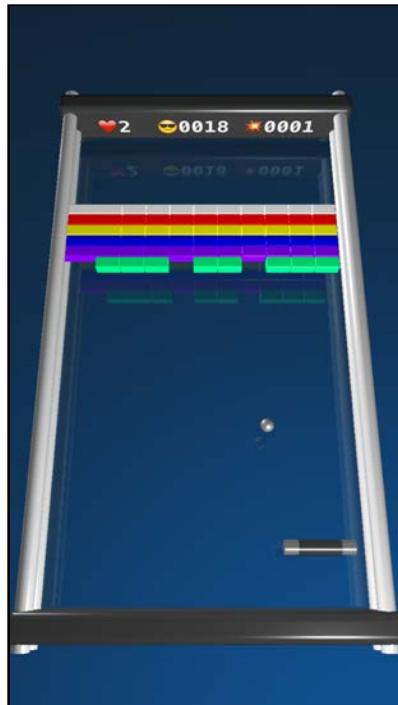
```
override func touchesMoved(_ touches: Set<UITouch>, with event: UIEvent?)  
{
```

```
for touch in touches {  
    // 1  
    let location = touch.location(in: scnView)  
    paddleNode.position.x = paddleX +  
        (Float(location.x - touchX) * 0.1)  
    // 2  
    if paddleNode.position.x > 4.5 {  
        paddleNode.position.x = 4.5  
    } else if paddleNode.position.x < -4.5 {  
        paddleNode.position.x = -4.5  
    }  
}
```

Similar to before, you override `touchesMoved(_:with:)` to detect when the user moves their finger around the screen. Here's a closer look at the code:

1. As the touch location moves, this updates the paddle's position relative to the initial touch location stored in `touchX`. It's a technique that allows the paddle to move left and right as if you were using the screen as a touchpad.
2. This simply limits the paddle's movement and confines it between the barrier's limits.

Build and run, and you can now drag to move the paddle across the screen:



Camera tracking

You're thinking in 3D, but the game's cameras are still living in 2D. A really simple, yet effective way to demonstrate the 3D nature of your game would be to let the cameras track the paddle around as it moves across the screen.

Woo-hoo! It's time to introduce some larger than life (and possibly motion sickness inducing) effects! :]

Adding camera tracking

To add some basic tracking, add the following lines of code to the bottom of `touchesMoved(_:with:)`:

```
verticalCameraNode.position.x = paddleNode.position.x  
horizontalCameraNode.position.x = paddleNode.position.x
```

This updates both cameras' x-position to be the same as the paddle, allowing the cameras to track the paddle's every move. It gives a really cool effect. Build and run to try it out for yourself!

Adding camera constraints

You're making progress, but there's a problem with the tracking at the moment: The cameras scroll too far to the right and left, leaving the player without a view of the play area.

It's easy to solve this by pointing the cameras to the center of the play area where the floor node is positioned. You'll add constraints to the camera to accomplish this.

Add a new property to store the floor node in `GameViewController`:

```
var floorNode: SCNNode!
```

This will be where you store the floor node once you've found it in the scene.

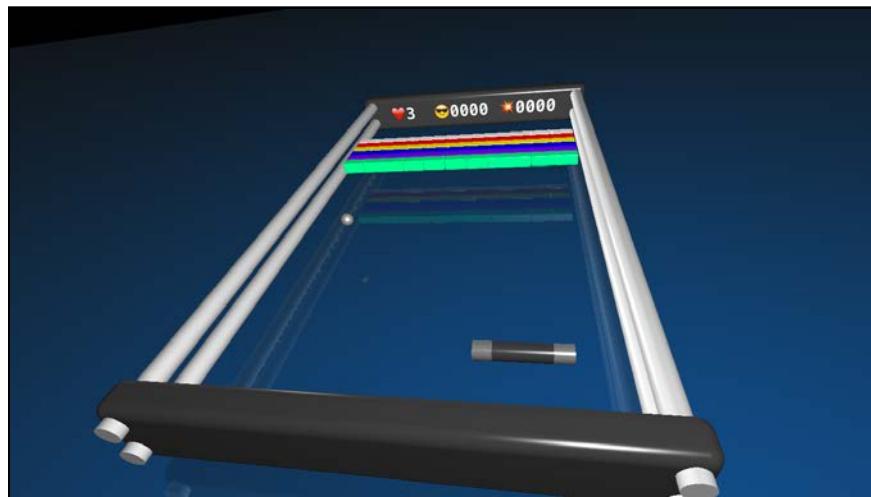
Next, add the following to the bottom of `setupNodes()`:

```
floorNode =  
    scnScene.rootNode.childNode(withName: "Floor",  
        recursively: true)!  
verticalCameraNode.constraints =  
    [SCNLookAtConstraint(target: floorNode)]  
horizontalCameraNode.constraints =  
    [SCNLookAtConstraint(target: floorNode)]
```

This bit of code finds the node named **Floor** and binds it to `floorNode`. Then, it adds a `SCNLookAtConstraint` to both cameras in the scene, which will force the camera to point towards the targeted node.

Remember that the floor is positioned underneath the center of the play area. So now, no matter where you move the cameras, they're always looking toward the center of the play area.

It's time to try all these awesome new features out, so build and run your game.



Excellent! Slide your finger left and right across the screen, and experience the sheer joy of moving the paddle across the screen. What's even cooler is how the camera tracks the paddle wherever it goes, but it always keeps on its eye on the center of the scene.

Add a trailing effect

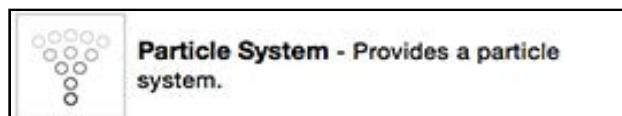
You've probably seen the trailing effect in other *Breakout* style games — the ball leaves a streak in its wake. With a particle system, you can add this effect with relative ease.

Adding a particle system to the ball

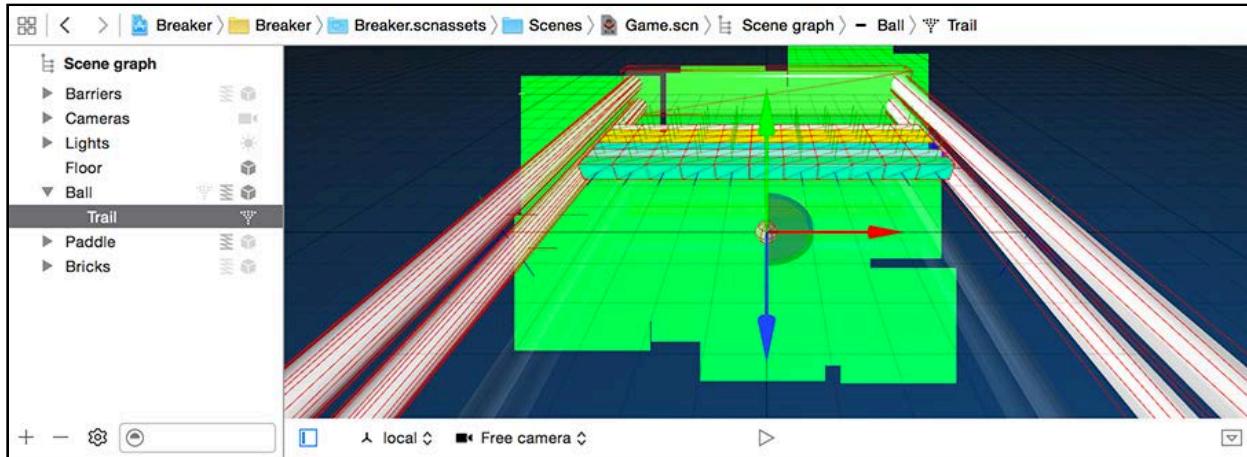
You're going to use the SceneKit editor to add a particle system to the ball this time around. It sounds rather futuristic, doesn't it?

Start off by selecting your game scene again under **Breaker.scnassets/Scenes/Game scn**.

Drag and drop a **Particle System** from the Object Library to your scene:



Name this node **Trail** and reorganize the scene graph so that the particle system is a child of **Ball**:

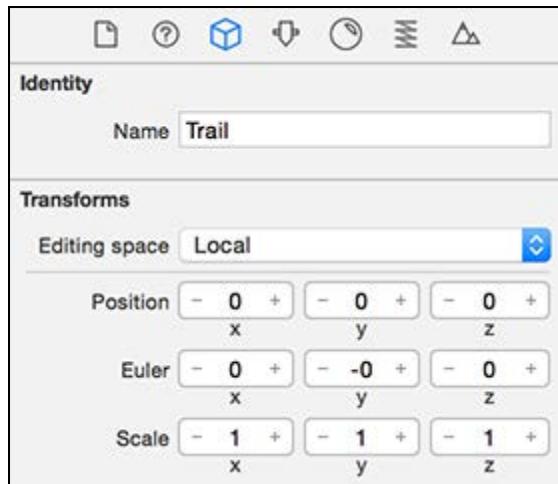


What you're doing is allowing the particle system to be positioned relative to its parent, the ball. When the ball bounces around, the particle system will move along with it.

As soon as you drop the particle system into your scene, it emits big, ugly squares. Don't be alarmed; you've done nothing wrong. :]

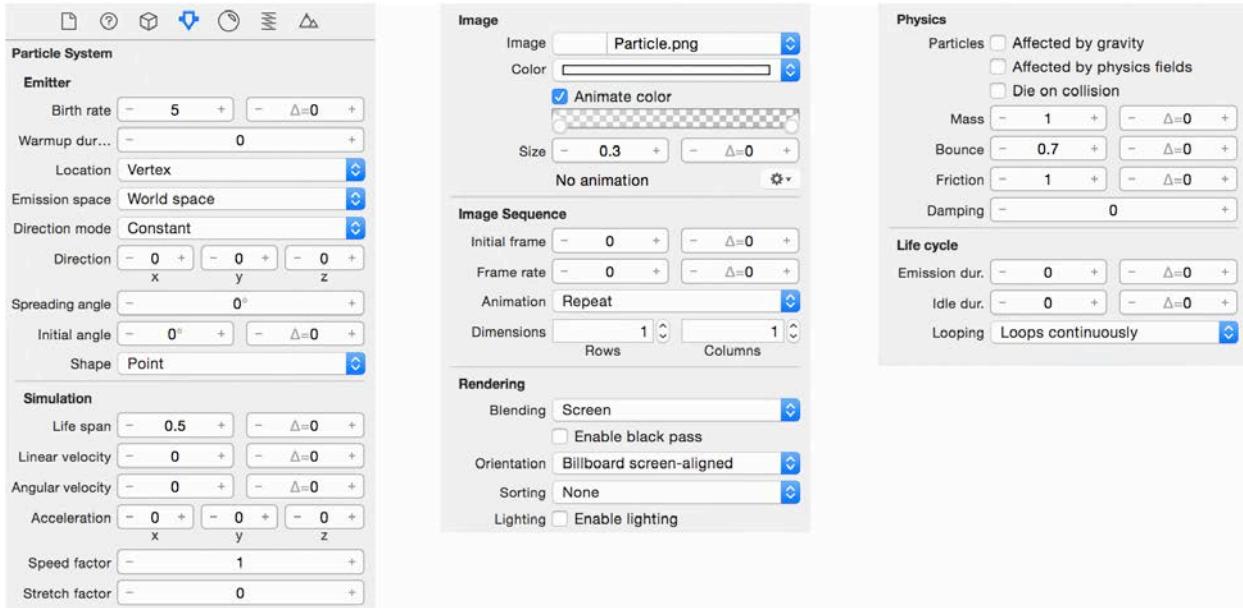
The reason why it looks like a hot mess is because you still need to give the particle system a proper image to use for each particle it emits.

This is your next bit to fix up, so first make sure your particle system is positioned correctly by opening the Node Inspector. Zero out its position to ($x:0$, $y:0$, $z:0$).



Now the particle system should start emitting particles smack bang from the center of the ball. Getting better already.

Next, select the Attributes Inspector to configure the properties of the particle system.



You need to configure the particles so they fade away and are emitted right from the center of the system. Because the particle system moves with the ball, it'll create the effect of a trail behind the ball.

Take a look at the properties you'll change from the defaults.

Note: The first part of each point below calls out the field followed by the setting. An explanation of what you're doing comes after the colon.

- **Birth rate** to **5**: This controls how often particles spawn. An increase here makes the particles more dense.
- **Location** to **Vertex**: This controls the particles' spawn point.
- **Direction mode** to **Constant**: This controls how to launch the emitted particles from the emitter. **Constant** applies a constant vector to each particle.
- **Direction** to **(x:0, y:0, z:0)**: This zeros out the constant directional vector that gets applied to the particles once they spawn so they stay in place.
- **Life span** to **0.5**: This controls the particles' life span; go ahead and play with this setting to lengthen or shorten the trail.
- **Linear velocity** to **0**: The particles will not move after being spawned.
- **Image** to **Particle.png**: You can find this image under **Breaker.scnassets/Textures**. All particles spawned from this system will use this image as their texture.
- **Color** to **White**: This sets the overall tint color over the particles' texture.

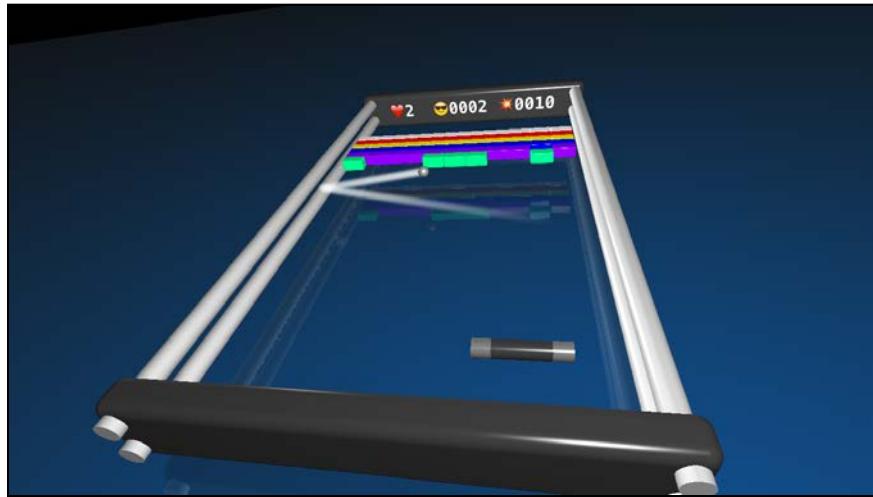
- **Animate color:** Enables the checkbox, and once you enable this, a bar appears to allow you to specify how to animate the tint color over the particle's life span. It's where you create a fade effect! So, create two markers and place them on the beginning and end of the timeline. Set the color for each so that it animates from **White** at 50 percent **Opacity** to **White** at 0 percent **Opacity**. Note that to remove markers, you just drag them off the track and release when an X appears.
- **Size to 0.3:** This scales the particle down to 30 percent of its original size as determined by the image.
- **Blending to Screen:** This controls how the particles are drawn, as well as where multiply mode darkens and screen mode lightens.
- **Emission duration to 0.** This controls how long the particle system emits particles. Since you really want it to emit perpetually, set it to 0.

All done! Click the play button at the bottom of the editor to see the resulting effect:



Just look at that pretty tail, it's just like Halley's Comet! :]

Time to build, run and play! :]



Look at all those little details you added to the game: the trailing effect, the camera movement and the gameplay-oriented camera that always keeps its eye on the prize. Way to go!

Note: You can find the completed project up to this point under the **projects/final/Breaker** folder.

Challenge

Excellent, your core game is done, but the hardest part is still left: adding juice! By juice, I mean sound effects.

Add the following lines of code to `setupSounds()`:

```
game.loadSound(name: "Paddle",
    fileName: "Breaker.scnassets/Sounds/Paddle.wav")
game.loadSound(name: "Block0",
    fileName: "Breaker.scnassets/Sounds/Block0.wav")
game.loadSound(name: "Block1",
    fileName: "Breaker.scnassets/Sounds/Block1.wav")
game.loadSound(name: "Block2",
    fileName: "Breaker.scnassets/Sounds/Block2.wav")
game.loadSound(name: "Barrier",
    fileName: "Breaker.scnassets/Sounds/Barrier.wav")
```

This will use a helper method to load a whole bunch of sounds into memory from **Breaker.scnassets/Sounds**. You'll find them stored in a dictionary with named keys for simple access later on.

Now, see if you can play the right sound at the precise moment of contact. Here are some hints:

- Use `game.playSound(node: scnScene.rootNode, name: "SoundToPlay")` to trigger one of the named sound effects you loaded beforehand.
- Give the **Block** sound effect some randomness by using `random() % 3` to generate a random number from 0 to 2.

Good luck! :]

Note: You can find the completed challenge project for this chapter under the **projects/challenge/Breaker** folder.

Where to go from here?

You just finished yet another game and had another stellar performance! Are you sure you're not a machine? I think you might just have some machine-like qualities, so well done, you T-1000! :]

You've come a long way and have a lot more smarts when it comes to 3D games, too. In this chapter, you covered a lot of different topics:

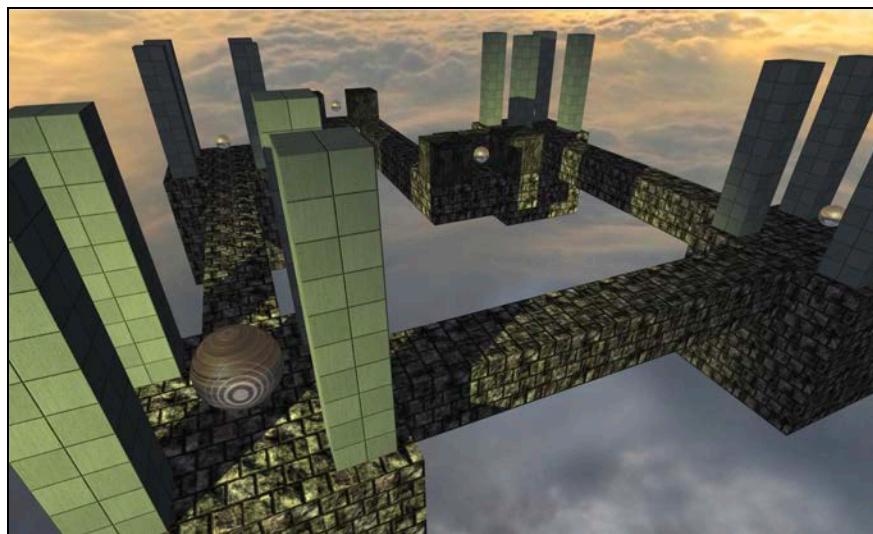
- **Physics Inspector:** You learned how to enable and configure physics bodies for all the nodes in your game, right inside of the SceneKit editor.
- **Basic Collision Detection:** You learned how to use the `SCNPhysicsContactDelegate` protocol to listen to collision events in your game and responded by adding game logic in code.
- **Juice:** You just scratched the surface of adding "juice" to your game by adding a particle system to display a trail effect on the ball, and you had the added challenge of getting sounds to play at the right moments.

With that said, there's always room for improvement and more juice! Here are some ways you could take it up a notch:

- The game still needs some basic state management, which would allow you to transition between different states for your game, for instance, `tapToPlay`, `playing` and `gameOver` states.
- The physics still needs a bit more tweaking to ensure the ball doesn't fall into an eternal bounce between the side barriers.
- The game definitely needs more juice too! Think about special bricks, special effects, levels, etc. :]

Section III: Intermediate SceneKit

In this section, you'll create a stunning make-believe world, where exceptional balancing skills are needed to guide a shiny wooden relic through a maze high up in the sky. The game is named Marble Maze, and is somewhat based on the *Labyrinth* styled games — with a twist.



[Chapter 11: Materials](#)

[Chapter 12: Reference Nodes](#)

[Chapter 13: Shadows](#)

[Chapter 14: Intermediate Collision Detection](#)

[Chapter 15: Motion Control](#)

Chapter 11: Materials

Chris Language

Getting started

Take a moment and look around. Pick up something close by and examine it. Aside from its geometrical shape, what makes the object look the way it does? What do you see or feel?

Consider the shiny football below — or for our American friends, the shiny soccer ball:



It looks quite realistic; wouldn't you agree? Believe or not, that's all generated in real time within SceneKit.

See if you picked up on the following qualities of the ball:

- See how each patch bulges out? You can even notice the stitching between the patches.
- Do you see the bumpiness of the leather texture as the light bounces off?
- How about the shiny polished parts that contrast with the matte RW logo on the black patches?
- Do you notice the three rectangular lights from the ceiling reflecting off the ball?
- What about the dark floor reflecting off the bottom of the ball?
- Can you see how light struggles to reach the deep ridges between the patches?

You're probably thinking that all that added detail puts the polygon count off the charts! Well, think again. It's all just eye trickery, because what you're seeing is just a basic sphere wrapped with different types of special materials. Surprised?

The following sections show the details of each material and how it helps contribute to the overall effect.

Lighting models

SceneKit supports a few different lighting models, which define mathematical equations that combine the properties of different materials with the lights in the scene to produce the exact final color of every rendered pixel.

Here's a representation of the different models available in SceneKit:



Here's each model in detail:

- **Constant:** Uses a flat lighting model that only incorporates the ambient lighting into the equation when calculating the color of a rendered pixel.
- **Lambert:** Incorporates ambient lighting and diffuse information when calculating the color of a rendered pixel.
- **Blinn:** Incorporates ambient, diffuse and specular lighting information, where the specular highlights are calculated using the Blinn-Phong formula.

- **Phong.** Incorporates ambient, diffuse, and specular lighting information, where the specular highlights are calculated using the Phong formula.
- **PBR:** *Physically Based Rendering* incorporates diffuse with a realistic abstraction of physical lights and materials.

Note: You'll use the Phong model in this chapter so you can see all available effects.

Materials

A material defines a basic lighting model, along with various properties used to define the material, like its color, specularity, reflectivity, shininess, roughness and even transparency.

Materials makes use of solid colors or textures for more refined detail to define the various properties of the material itself.

Textures are essentially flat 2D images wrapped around your 3D geometry that use special **texture coordinates** stored within the geometry. All SceneKit's built-in shapes already contains this information out-of-the-box, so all you need to do is provide them with some pretty textures to make them pop.

All the effects on the ball above were created through different types of texture maps: one to give the ball its base color, another to make certain parts bumpy, another to make certain parts shiny or matte, and so forth.

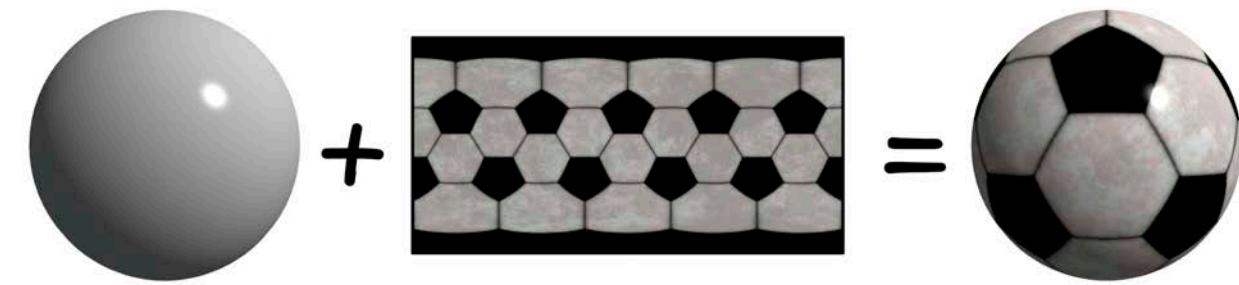
To understand how each texture works, you'll see how that shiny ball was created from scratch. Get ready for some material mathematics! :]

Note: Just for fun, there's a little starter project under the **projects/starter/SoccerBall/** folder. Start off with **ball.scnassets/00_Start.scn** scene.

Select the **Ball** node, then select the **Material** inspector. See if you can follow the steps below to re-create the final effect yourself. Alternatively, just use the provided solution step to have a more hands-on experience of the resulting effect.

Diffuse map

The diffuse map gives your geometry a base coloring texture. This texture typically defines what your object is, regardless of lights and special effects:



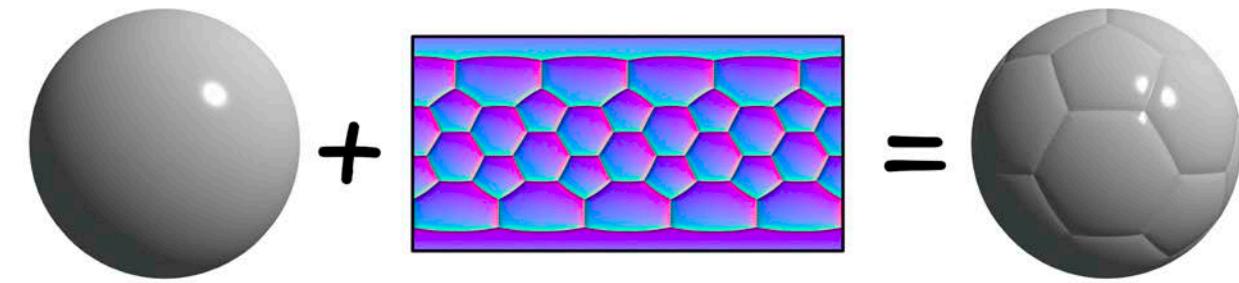
Adding the diffuse map clearly defines the sphere as a football. Looks like one of those cheap \$2 plastic balls that wouldn't even last five minutes with your dog, doesn't it? :]

Note: Select the **01_Diffuse.scn** scene to see this effect in action.

Normal map

The normal map feels like sorcery from another planet. Recall the discussion from Chapter 8, “Lights”, about how lights use the normal vector to shade and light up a surface. Now combine that single surface normal vector with a whole bunch of detailed normal vectors that define exactly how each pixel on your surface will bend the light, and you’ve got your normal map.

Think of the normal map as a texture that defines the *bumpiness* of your geometry; you can use it to simulate rough surfaces such as the craters on the surface of the moon, engravings on an ancient stone tablet, or perhaps even the bulging patches and leather pattern on a shiny football:



Applying the normal map delivers one heck of a graphics punch; it’s taken a basic, dull-looking sphere to a detailed football bulging with awesomeness! :]

Note: Select the **02_Normal.scn** scene to see this effect in action.

Now see what happens when you add the normal effect to the existing diffuse effect:



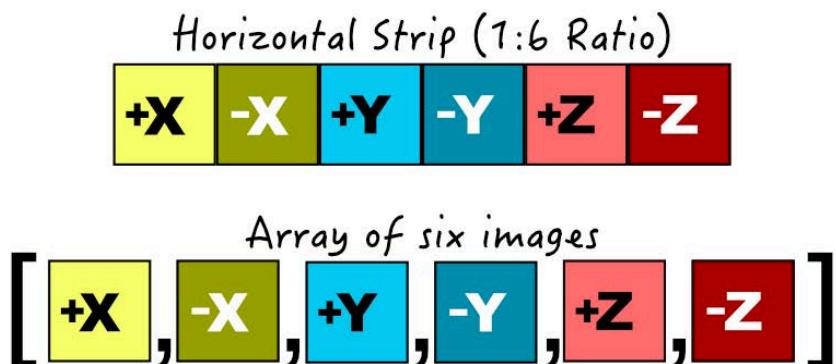
That certainly makes the ball pop out — no pun intended! Suddenly, your \$2 ball becomes a \$20 ball. Awesome! But don't celebrate just yet; you can make it look even better.

Note: If you want to generate your own normal maps, there's an awesome tool called *CrazyBump*. You can find it at crazybump.com. Hurry, while it's still in beta for Mac owners.

Reflective map

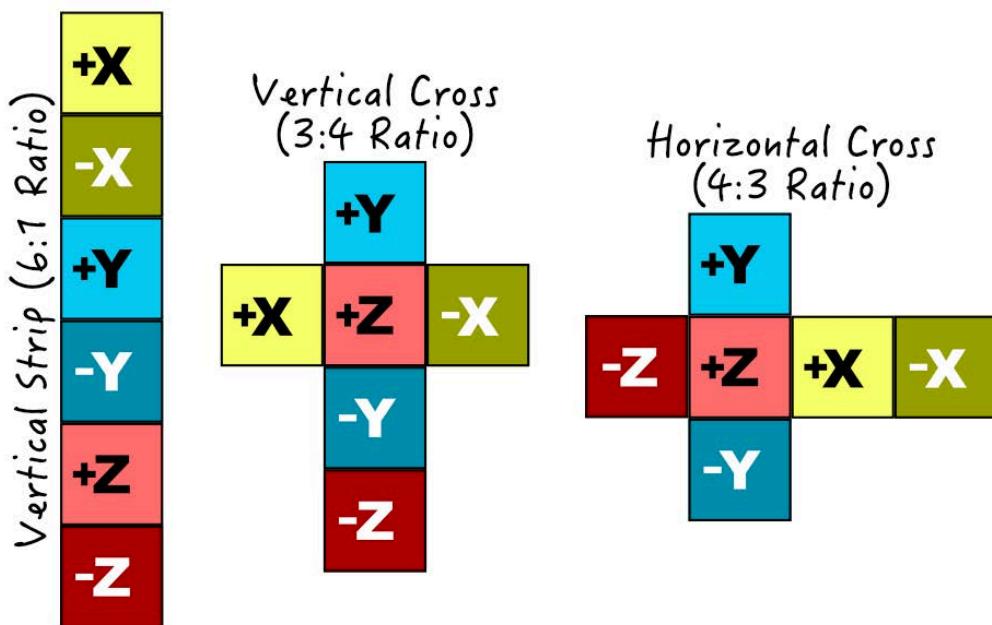
Before diving into reflective maps, you first need to understand the concept of **cube mapping**. You know that a cube consists of six sides. Similarly, a cube map consists of six equally sized textures, all contained within one large map used to texture all sides of a cube.

With the release of Xcode 8, SceneKit now supports various patterns for cube maps. For starters, you can make use of a **Horizontal Strip** by providing a 1:6 ratio image, or even programmatically create an **array** of six equally sized textures:

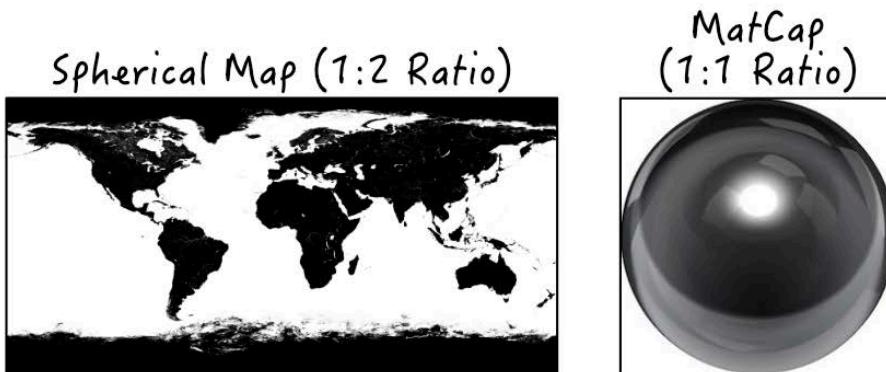


Note: Think of **+X** and **-X** as the right and left faces. Then **+Y** and **-Y** as the top and bottom faces. Then finally **+Z** and **-Z** as the near and far faces of a cubemap.

You can also make use of a **Vertical Strip** by providing a 6:1 ratio image. A **Vertical Cross** by providing a 3:4 ratio image, and a **Horizontal Cross** by providing a 4:3 ratio image:



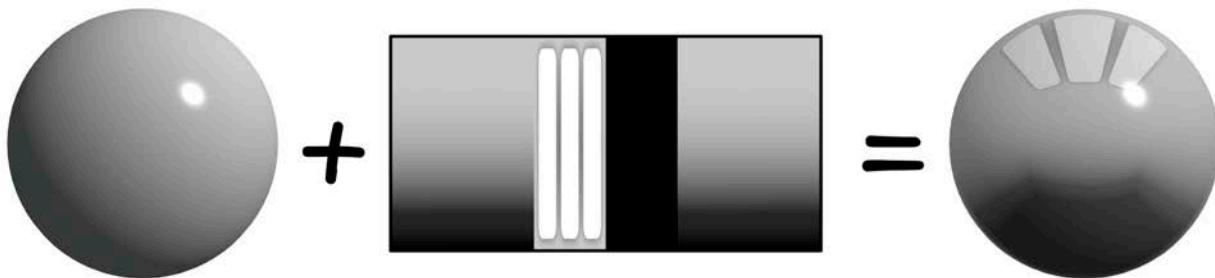
Finally SceneKit also supports the use of **Spherical Maps** by providing a 1:2 ratio image, and also **MatCaps** by providing a 1:1 ratio image:



Note: Make a mental note of cube mapping and how SceneKit uses it, because you'll see it again for a different effect.

A reflective map, as the name might suggest, defines reflection. The beauty of using a cube map is that you can define details on your object; the reflectiveness of your object determines how much of this reflection will be visible. For instance, a mirror finish would make your object highly reflective and produce a chrome effect.

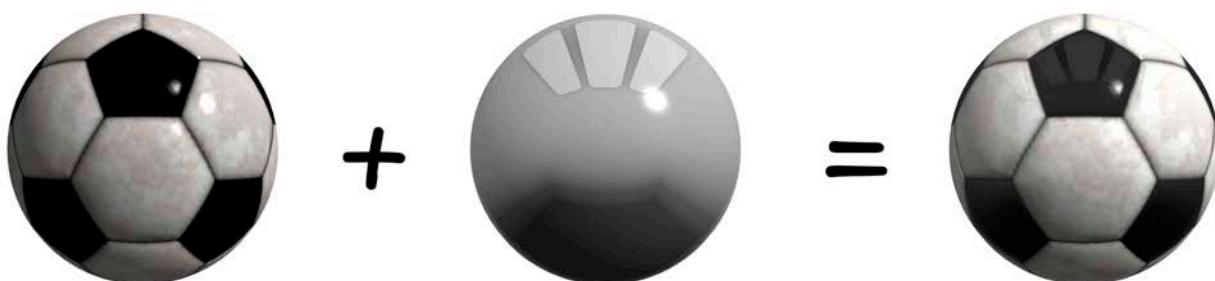
Time to create a little light room for the ball:



The light room has three ceiling lights and a dark floor. Note that the reflectiveness has been toned down quite a bit; the ball is shiny and reflective, but it's not a mirror ball either.

Note: Select the **03_Reflective.scn** scene to see this effect in action.

See what happens when you combine the results of this effect with the previous effects:

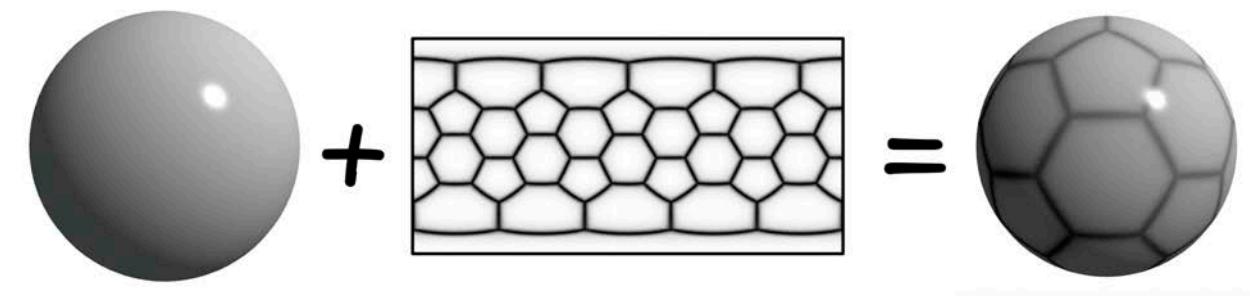


This effect makes the ball even shinier than before. Although subtle, it's still an effective way to provide realism to your objects.

Occlusion map

The occlusion map, also known as the **ambient occlusion map**, is only effective when ambient light exists in your scene. This black-and-white texture map defines how much ambient light reaches certain parts of your geometry; black parts block out ambient light entirely, while white allows all ambient light to shine through.

When it's done well, the occlusion effect lends a lot of realism to a scene. For complex geometrical forms, portions of the geometry will block ambient light from other spots of the geometry, such as the deep ridges around the patches of the ball:



Note: Select the **04_Occlusion.scn** scene to see this effect in action.

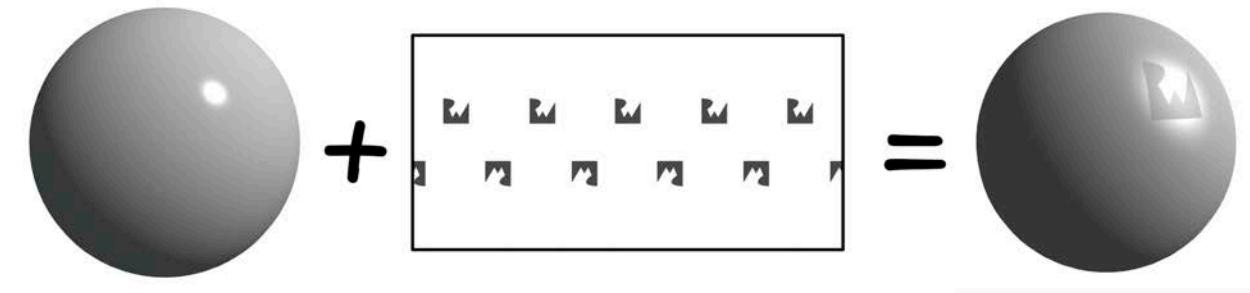
Here's what the effect looks like combined with the previous effects:



It's a subtle effect, but it still shows how occlusion mimics the natural properties of light.

Specular map

The **specular map** controls the *shininess* of your geometry. Black sections of the map define matte portions, while white sections indicate a glossy effect:



See how the RW logo appears as matte and blocks out all light from the reflective map and the shiny specular light reflection?

Note: Select the **05_Specular.scn** scene to see this effect in action.

You'll get the following effect when you add the specular map to the existing effects in your scene:

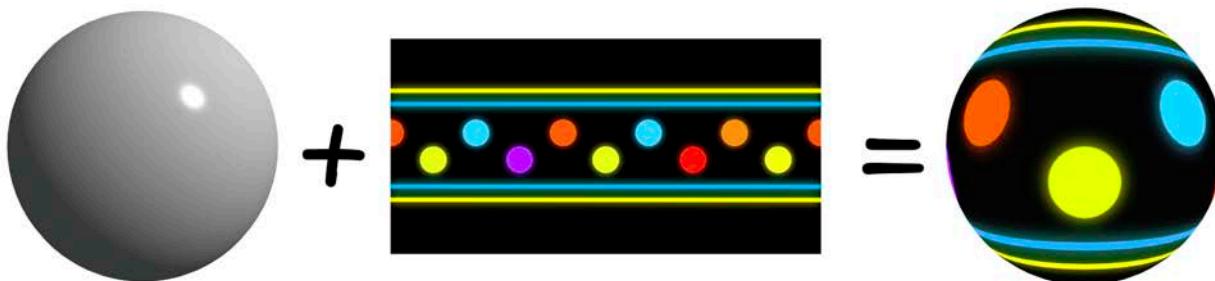


Again, it's very subtle, but this effect adds more depth and realism to your scene, bringing you to the final result of a very shiny \$50 football! :]

Emission map

In the absence of light, the ball wouldn't be visible at all. But if you slapped some phosphorous paint on it, you could make it glow in the dark!

The **emission map** overrides all lighting and shading information to create a light-emitting effect, which is even more pronounced when you add some blur effects to the map. This is a colorized texture where the brighter colors emit most strongly, darker colors emit less and absolute black emits nothing at all:



Note: Unlike many 3D authoring tools, the emission map doesn't generate light in SceneKit; it merely simulates the emission effect. Select the **06_Emission.scn** scene to see this effect in action.

When you dim the lights a bit and apply the emission effect to the ball, you'll see it light right up:



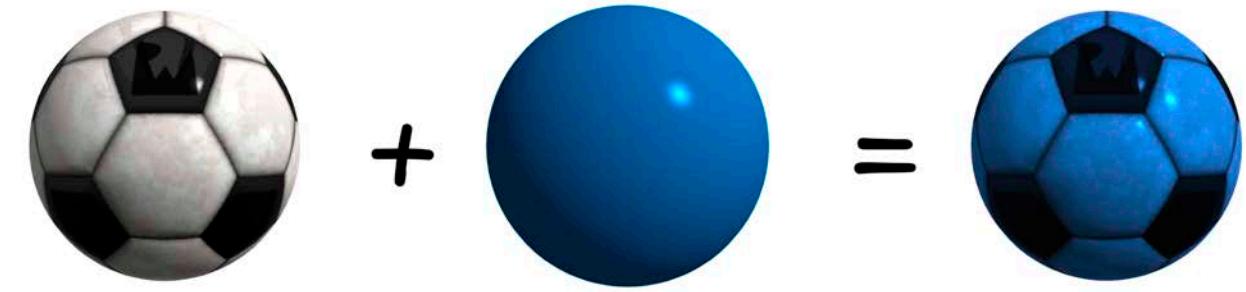
You don't have to worry about lights anymore; this puppy glows in the dark! :]

Multiply map

The **multiply map** is applied after all other effects; it can be used to colorize, brighten or darken the final result:



Add the multiply effect to ball and you'll get the following:



Transparency map

Transparency maps make parts of your geometry transparent, or even completely invisible. Black sections define opaque sections, while white parts end up as transparent:



If you enable double-sided mode, you'll be able to see right through the object.

Note: Select the **07_Transparency.scn** scene to see this effect in action.

If you add the transparency effect to your ball, you'll end up with a ball that defies the laws of physics:

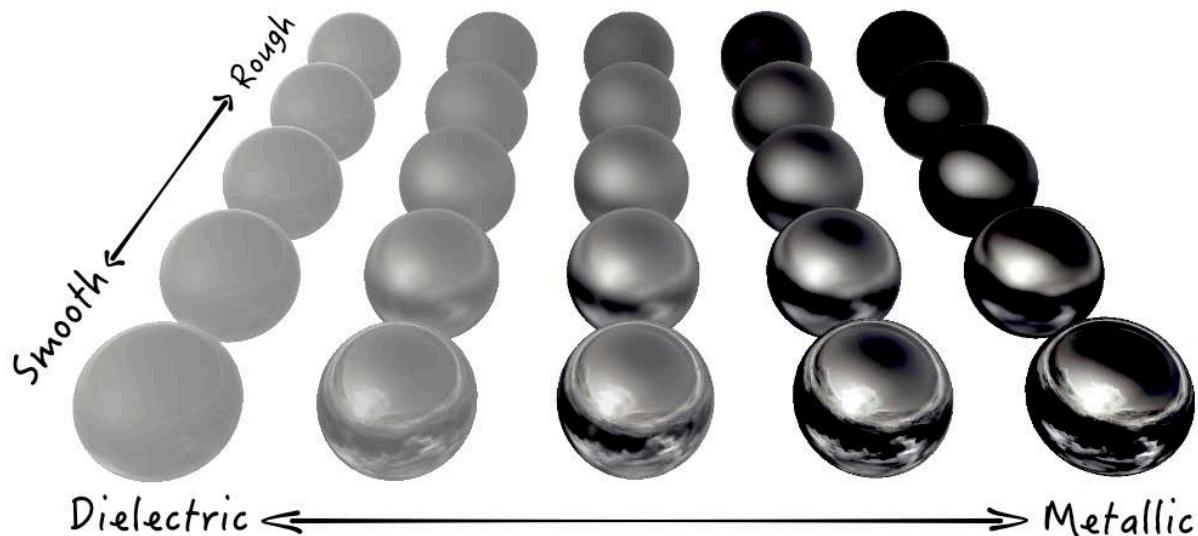


It's like an alien football from a different dimension!

Note: To see the final result select **08_Final.scn**. Also have a look at steps 09, 10 and 11 to see the Multiply, Emission and Transparency maps in action.

Metalness and Roughness maps

Introduced with Xcode 8, the Physically Based Rendering (PBR) lighting model makes use of **Metalness** and **Roughness** maps. PBR produces a much more realistic result than any of the other available models, because it incorporates physical based lighting, environmental lighting and physical material properties into its shader calculations. It does not, however, include ambient, specular or reflective material properties.



- **Metalness:** This property approximates physical surface properties like refraction, reflection and Fresnel reflections at low angles. It produces a metallic or dielectric (non-metallic) appearance. You can provide a grayscale color or texture for more detail.
- **Roughness:** This property approximates microscopic detail of real-world surfaces. It produces a shiny or matte appearance. You can also provide a grayscale color or texture for more detail.

Note: To see the final result that makes use of PBR, select **12_Final +PBR.scn**. Also have a look at **13_MetalnessVSRoughness** to see the PBR based materials in action.

The game project

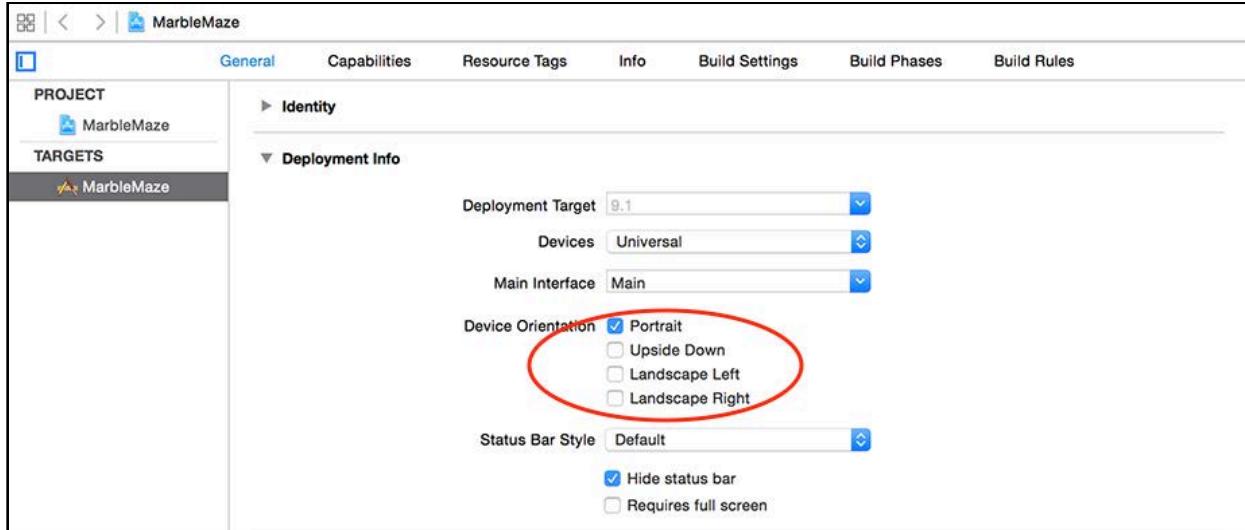
The good news is that you're all done with materials theory, but the bad news is that you haven't yet begun to build your stunning game! Time to take care of that.

Creating the SceneKit game project

To keep things easy, you'll start with the built-in SceneKit game template. Here's the super-short version of the setup:

1. Open up Xcode, create a new SceneKit game project for **iOS** and name it **MarbleMaze**.
2. Delete the **art.scnassets** folder.

3. Drag and drop the new **art.scnassets** folder from the **resources** folder into the project.
4. You'll only play the game in portrait mode, so uncheck **Landscape Left** and **Landscape Right** to disable the other orientations:



Now you can replace the contents of **GameViewController.swift** with the following lines of code:

```
import UIKit
import SceneKit

class GameViewController: UIViewController {

    var scnView:SCNView!

    override func viewDidLoad() {
        super.viewDidLoad()

        // 1
        setupScene()
        setupNodes()
        setupSounds()
    }

    // 2
    func setupScene() {
        scnView = self.view as! SCNView
        scnView.delegate = self
        scnView.allowsCameraControl = true
        scnView.showsStatistics = true
    }

    func setupNodes() {
    }

    func setupSounds() {
    }
}
```

```
override var shouldAutorotate : Bool { return false }

override var prefersStatusBarHidden : Bool { return true }
}

// 3
extension GameViewController: SCNSceneRendererDelegate {
    func renderer(_ renderer: SCNSceneRenderer,
                  updateAtTime time: TimeInterval) {
    }
}
```

This code snippet should look familiar; it's the same bare-bones **GameViewController** class you used in the previous sections.

Here's a closer look at the commented sections:

1. These stub methods are called from `viewDidLoad()`; you'll add code to these methods to set up your game.
2. This simply casts `self.view` as an **SCNView** and stores it for convenience. It also sets the render loop **delegate** to `self`.
3. The class now conforms to the **SCNSceneRendererDelegate** render loop protocol and contains a stub that is called on every frame update.

Note: For a more detailed version of these instructions, you can refer to the previous chapters of this book; for the rocket-fueled approach, simply load up the starter project from the **projects/starter/MarbleMaze/** folder. :]

Skyboxes

No, it's not the VIP seats at the stadium; rather, a **skybox** is a massive box around your scene that gives the impression of a real backdrop or scenery. Most 3D games today use this clever little trick to create an environment that resembles distant skies and hills for example.

All SceneKit scene camera nodes have a **background** property. You *could* simply set it to a specific color if that's all you wanted, but it has a hidden superpower: you can set the background to a cube map instead. SceneKit will detect the cube map and automatically create a massive skybox for you, with your cube map texture applied.

Note: As a reminder, a cube map is constructed of six equally sized images, all combined into one single large image. SceneKit uses various patterns to define cube maps.

You can also use a cube map to produce realistic environmental lighting for your Physical Based materials when using the PBR lighting model.

Creating a skybox

Inside **art.scnassets** you'll find an empty SceneKit scene named **game scn**. Open it and select the default **camera node**, then select **Scene Inspector** on the top right:



Find **img_skybox.jpg** from the Media Library at the bottom right and drag and drop it into the Background property of the scene.

Presenting the scene

All that's left to do is load and present the scene.

Add the following property to your **GameViewController** class:

```
var scnScene: SCNScene!
```

scnScene provides convenient access to the **SCNScene.scene** property.

Add the following lines code to `setupScene()`:

```
// 1
scnScene = SCNScene(named: "art.scnassets/game scn")
// 2
scnView.scene = scnScene
```

Taking a closer look at the code:

1. This creates an instance of **SCNScene** using your new scene. Note the specified path **art.scnassets/game scn** to the scene file.
2. This sets your new scene as the active scene for the view.

Build and run; take a look at the heavenly universe for your game:



Breathtaking, don't you think?

Where to go from here?

You can find the final project for this chapter under the **projects/final/MarbleMaze/** folder.

To recap some highlights from this chapter:

- **Lighting Models:** SceneKit supports several different lighting models, along with mathematical definitions of how different textures can be combined to determine the color of every rendered pixel.
- **Materials:** Various types of textures used together can create all sorts of special effects and details in your 3D models.
- **Skyboxes:** Cube map textures can create stunning skyboxes and environmental lighting in SceneKit.

In the next chapter, you'll get your hands dirty, build game assets from scratch and give them textures to make them look absolutely stunning.

12

Chapter 12: Reference Nodes

Chris Language

Getting started

Imagine for a moment you've created an epic monster, but you can't quite decide what color its eyes should be. Bloodshot red? Werewolf green? Zombie haze? To top it off, you've just spent hours scattering the monster all over your level, so when you *do* finally decide on the color, you'll have to go back and re-color all their eyes with the color you chose!

Fear not — **reference nodes** are here to save you from this scary scenario. :]

Reference nodes let you build your monster in its own little scene; when you're building your level, you can simply pull in a *reference* to the scene that contains the original monster. If you need to modify something on your monster, simply make the change in the original and the change will propagate to all referenced versions.

Using reference nodes saves hours of hard labor, and lets you make those difficult last-minute decisions without driving your graphics artists insane with change requests. In this chapter, you'll learn how to use them in your own games.

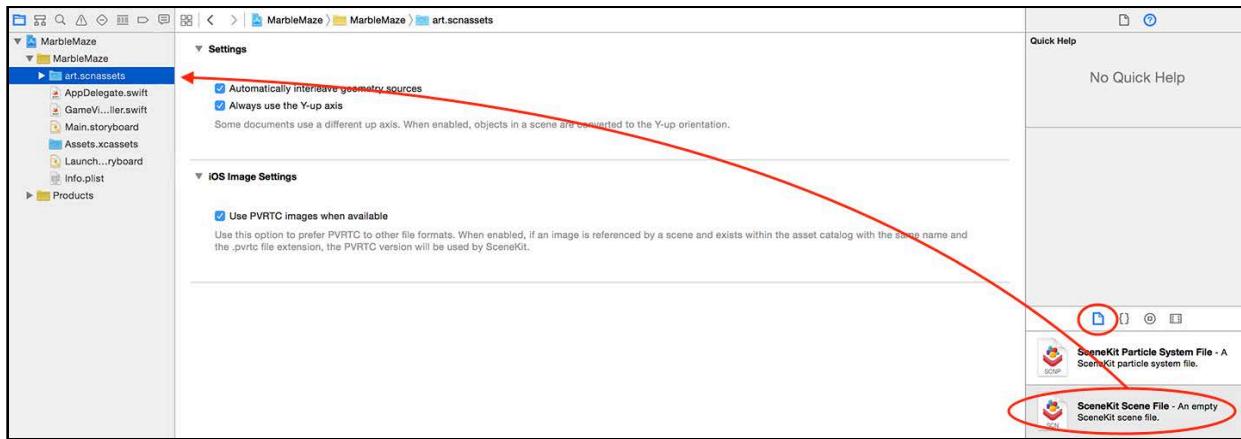
Note: You can continue with your project where you left off in the previous chapter, or alternatively you can begin with the starter project for this chapter found in **projects/starter/MarbleMaze/**.

The main character

The most important component of your game is your main character. For Marble Maze, this will be a marble — specifically, a shiny wooden relic. In the following steps you'll create a sphere inside its own little scene and apply a few different types of textures to make the relic look quite realistic.

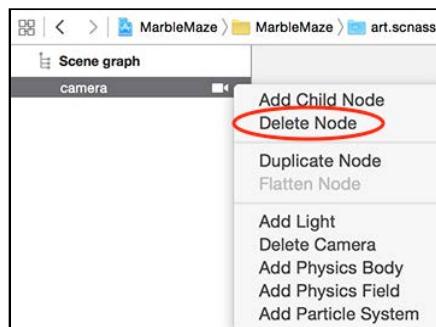
You'll create an empty scene that will hold only the geometry of the main character. Later, you'll reference this scene from another scene so that it becomes a reference node.

Start by dragging and dropping an empty SceneKit scene file into your project:

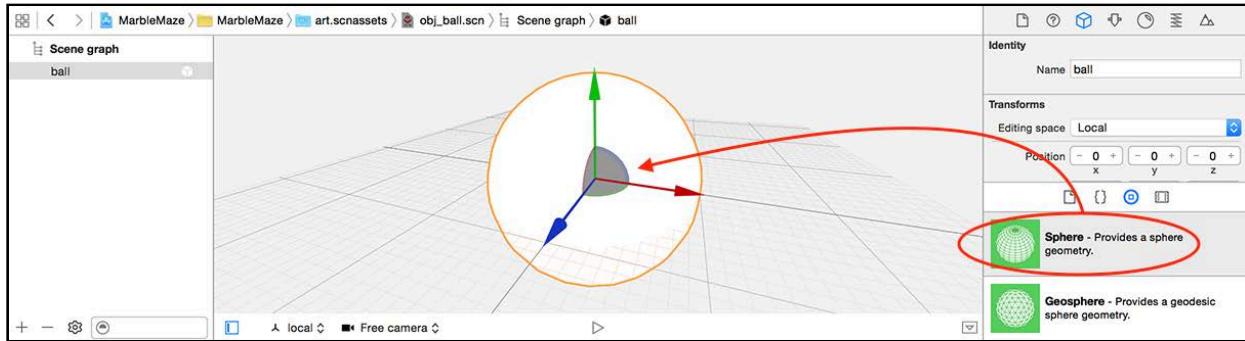


When prompted, select **art.scnassets** as the destination folder for the new scene and name the file **obj_ball scn**.

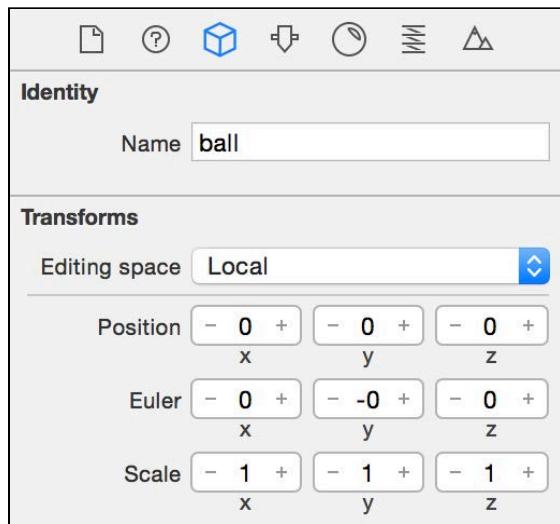
Select **art.scnassets/obj_ball scn**, expand the scene graph, then select the default camera node. All new empty scenes contain this default camera node, which is a real pain when you work with reference nodes. It's best that you get rid of it right away, before you continue. Select the default camera in your scene, then delete it like so:



Your wooden relic will start off life as a sphere. Drag a sphere from the Object Library into the scene:

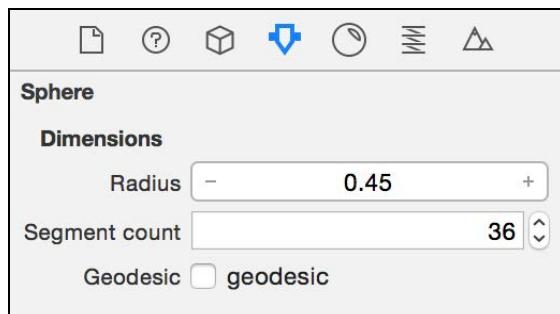


With the sphere still selected, select the Node Inspector. Name your new shape **ball** and place it at position **(x:0, y:0, z:0)** using the inspector:



The sphere is much too large at the moment, plus it needs some more detailed geometry.

Select the Attributes Inspector. Change the radius to **0.45** and bump up the segment count to **36**:



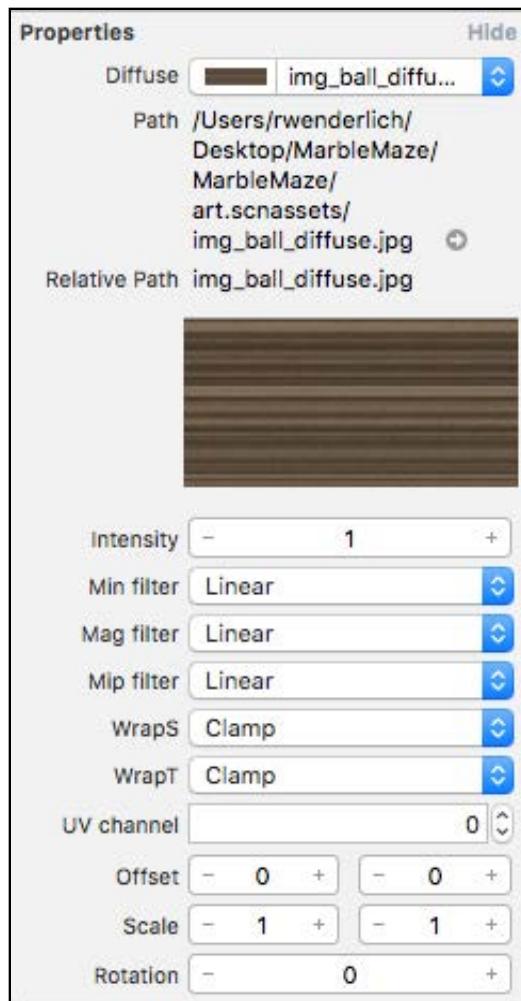
Changing the radius of the ball to 0.45 shrinks it to a size where it would easily fall through a 1x1 gap. Setting the segment count to **36** smooths out the sphere's geometry so that close up views of the sphere will appear more, well, spherical. :]

Materials

Now on to the fun part: adding materials!

Select the **Material Inspector** on the top right, and change the Diffuse, Normal, Reflective, and Emission settings as shown in the sub-sections below.

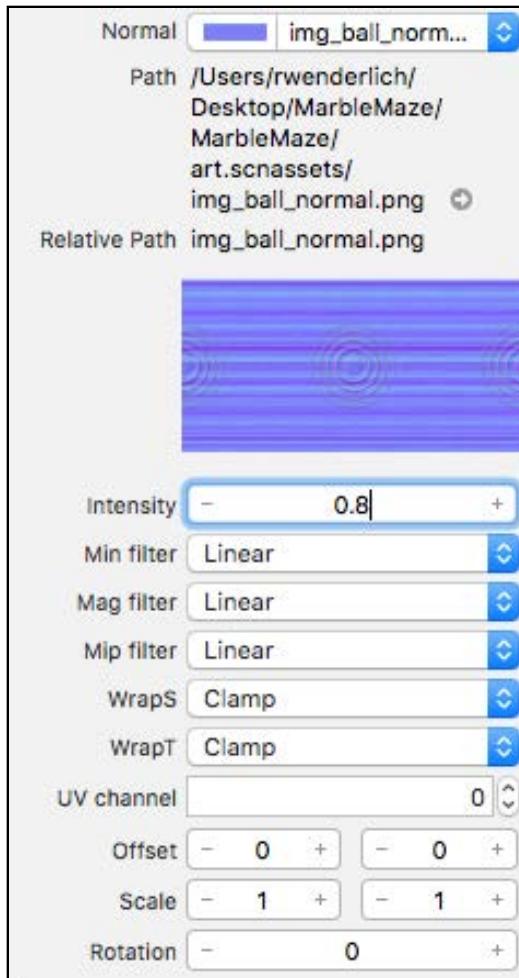
Diffuse settings



- **Diffuse:** Instead of a solid color, select **img_ball_diffuse** from the dropdown as the diffuse map. Note you must click to the far right of the dropdown where the up/down arrows are for this to work.
- **Intensity:** Leave this set to **1.0**. This controls the brightness level of your base diffuse material; **0.0** would make it completely black.
- **Mip Filter:** Set this to **Linear**, which enables mip mapping for the diffuse texture.

Note: Wondering what *mip* means? This will be discussed along with its brethren *min*, *mag*, *wrapT* and *wrapS* in the next section, so hold tight for a moment — there's need to scream and pull your hair out just yet. :]

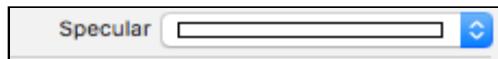
Normal settings



- **Normal:** Select **img_ball_normal** for the normal map.
- **Intensity:** Set this to **0.8** to make the effect just a little less prominent.
- **Mip Filter:** Set this to **Linear**.

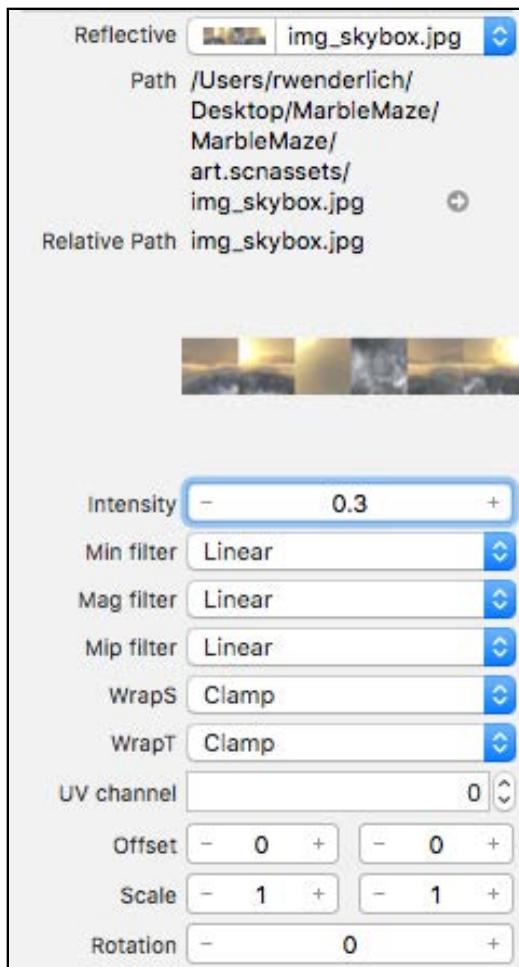
Note: If you want to use a different texture, as mentioned in Chapter 11, “Materials”, you can use the tool *CrazyBump* to generate a normal map from the diffuse texture.

Specular settings



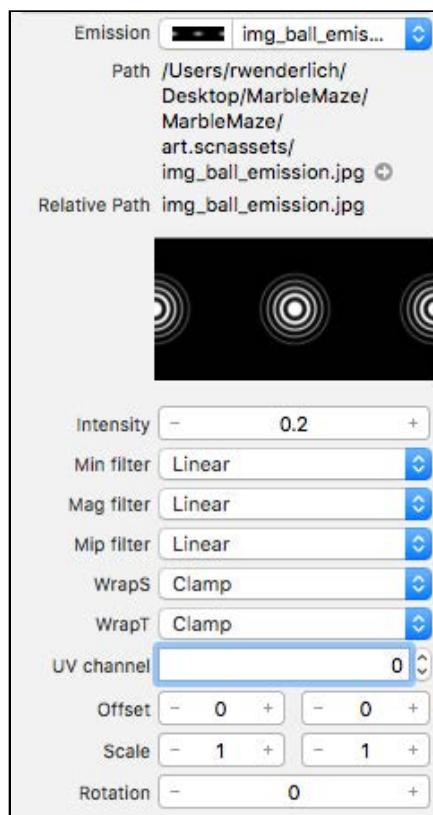
- **Specular:** Change the specular color to pure white, which gives the ball a nice glossy effect.

Reflective settings



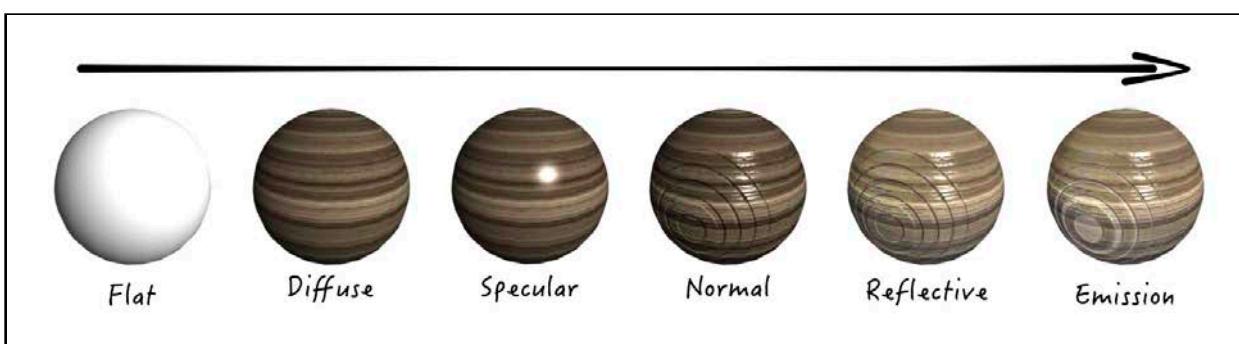
- **Reflective:** Select **img_skybox** for the reflective map. This reflects the environment onto the ball and makes it reflective like a mirror.
- **Intensity:** Set the intensity to **0.3** so it isn't perfectly reflective.
- **Mip Filter:** Set this to **Linear**.

Emission settings



- **Emission:** Select **img_ball_emission** for the emission map.
- **Intensity:** Set this to **0.2** for now; you'll animate the intensity later and change the emission map dynamically.
- **Mip Filter:** Set this to **Linear**.

The images below show the cumulative effect of adding each material type:



Note: You won't experience the exact same result as above while working in the scene editor. This is due to the lack of lights in your scene.

You've added some great detail to your sphere, but high-resolution textures can come at a serious performance cost. If you're viewing your objects from a distance, isn't it wasteful to use high-resolution textures on objects where the effect is only visible when you view the object up close?

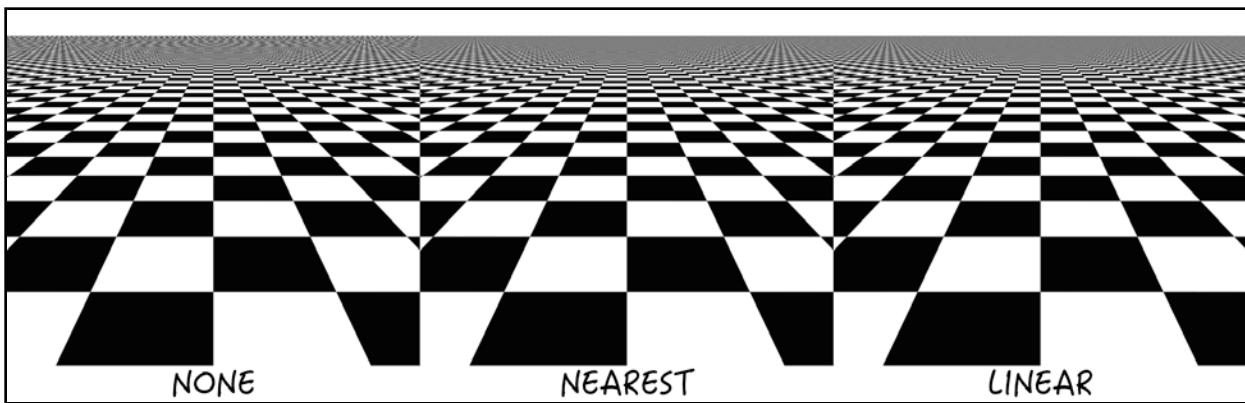
Yes, it can be wasteful, but you can use a technique known as **mip map filtering** to render your objects efficiently.

Texture filtering

3D rendering engines use the mip map filtering technique to speed up the rendering performance of textured objects at a distance; basically, you use a smaller, pre-generated versions of the original texture.

SceneKit indeed supports mip mapping; all you need to do is enable it (which it is by default) and decide which technique to use when generating smaller sized textures.

The results of mip mapping can be subtle; you might need a magnifying glass to spot the differences in the following images! :]



The image above shows three versions of the same scene of a patterned floor stretching to the horizon, each using a different mip mapping technique. Look closely at the appearance of the check pattern as it approaches the horizon:

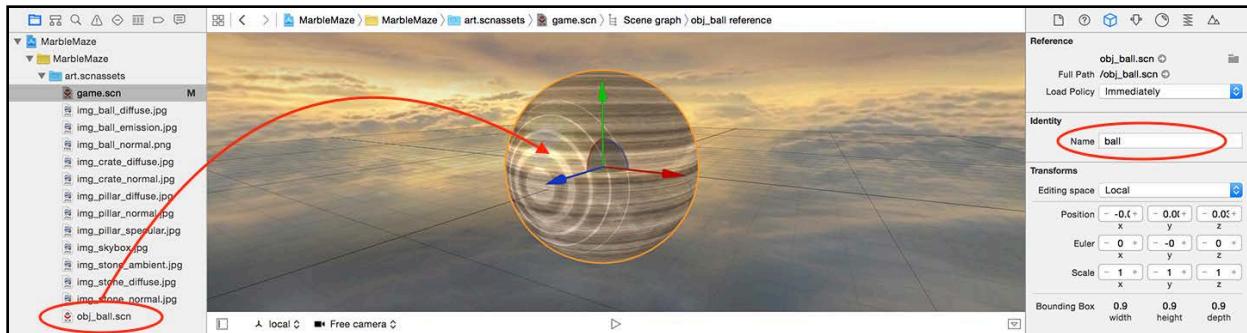
- **None:** This has no mip mapping enabled; note how the pattern generates all sorts of interesting visual artifacts and Moiré patterns near the horizon.
- **Nearest:** This samples pixels from the nearest level mip map when it textures a object.
- **Linear:** This samples pixels from the two nearest-level mip maps and interpolates the result between those two maps when it renders a object. This is the default option already selected when you choose a texture.

Note: The minification and magnification filters use the exact same techniques when dealing with textures at smaller or larger sizes than the original.

Adding the ball as a reference node

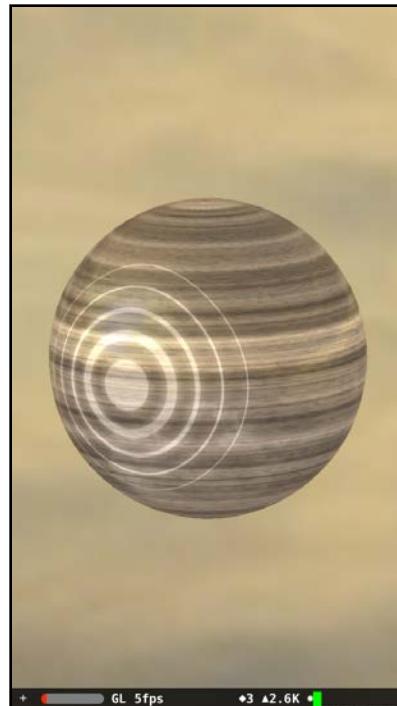
Now that you have your relic set up, it's time to pull it into the main game scene.

First select the **art.scnassets/game.scn** scene, then drag and drop the **art.scnassets/obj_ball.scn** into the scene. Set your relic's position to **(x:0, y:0, z:0)** and name it **ball**:



You'll see the wooden relic in your scene, but notice that its identity shows it's been added as a **reference**. Well done — you just mastered the dark art of reference nodes. :]

Build and run your game, and take stock of your scene:



Like magic, the wooden relic defies gravity and hangs in mid-air. Pan around and enjoy the view — but wait a minute. What happened to all those cool texture effects?

That's because there aren't any lights in the scene! Texture effects need light to be visible. You'll need to wait until the next chapter to add some light sources; for now, you'll focus on building the game level with reference nodes. Patience is a virtue. :]

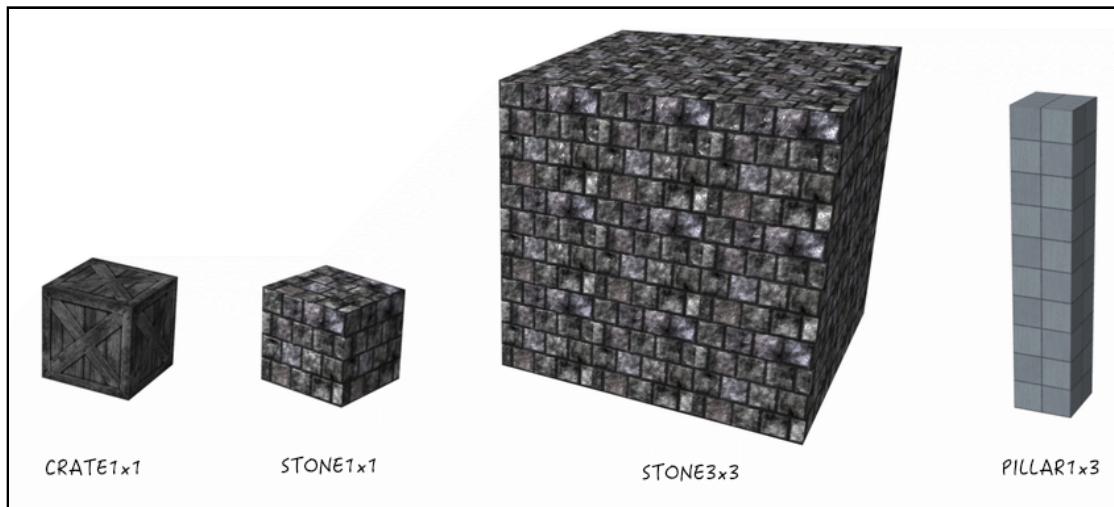
Note: At the time of writing this chapter, there appear to be a few bugs in the SceneKit Editor relating to reference nodes. When making changes to the origin node, the scene with the referenced version does not always get refreshed properly. If you run into this problem, simply make sure all your work is saved, then restart Xcode.

Challenge

Time for a fun little challenge! Simply read the following hints and apply the skills you've learned so far to create the objects below from scratch:

1. Create each object in its own little empty scene.
2. Delete that pesky default camera node from each empty scene; otherwise it will show up when you create a new reference to your object.

Okay — now try to create the following objects:



- **obj_crate1x1:** Name it **crate** and set its size to **(x:1, y:1, z:1)**. Use the **img_crate_diffuse** texture as diffuse, and **img_crate_normal** as normal. Add a mid-grey specular color; if you make this pure white, the crates will look like plastic.

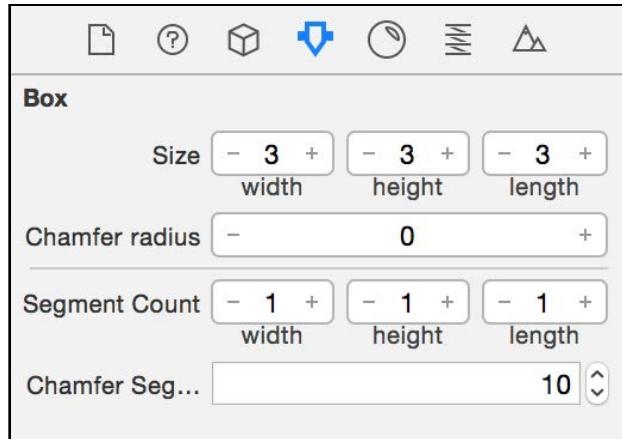
- **obj_stone1x1:** Name it **stone** and set its size to **(x:1, y:1, z:1)**. Use the **img_stone_diffuse** and **img_stone_normal** maps, but lower the normals intensity to **0.5**. Give it a nice **white** specular color.
- **obj_stone3x3:** Name this one **stone** as well, but set its size to **(x:3, y:3, z:3)**. This one will be a bit trickier, as you will have to use the texture scale settings and wrapT and wrapS to make it work. Use the same textures as you did for **obj_stone1x1**, and again use a **white** specular color.
- **obj_pillar1x3:** Name it **pillar** and set its size to **(x:1, y:3, z:1)**. Use the **img_pillar_*** textures; this one has a specular texture as well, so make use of that. You'll also have to play with the scale and wrap settings a bit.

Note: Don't freak out — you got this! Refer back to the previous section if you get stuck, or take a peek at the finished project located in the **projects/challenge/MarbleMaze/** folder. The section below walks you through the creation of the 3x3 stone block in particular.

Texture scaling and wrapping

Here's a little more detail on how to solve the challenge of the 3x3 block:

First off, adjust its size to **(x:3, y:3, z:3)** using the **Attributes Inspector**:

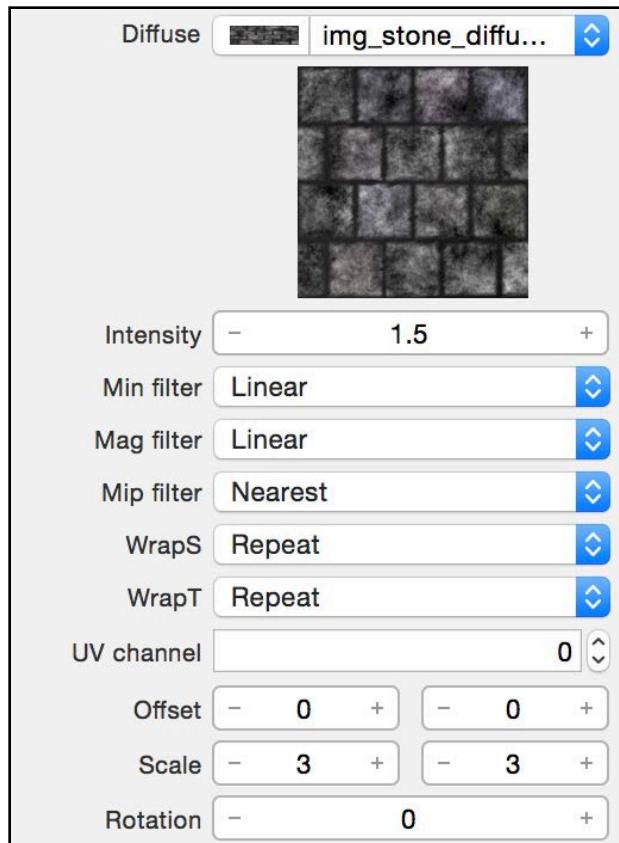


This is where things get interesting. Using the Materials Inspector, change each setting as described below:

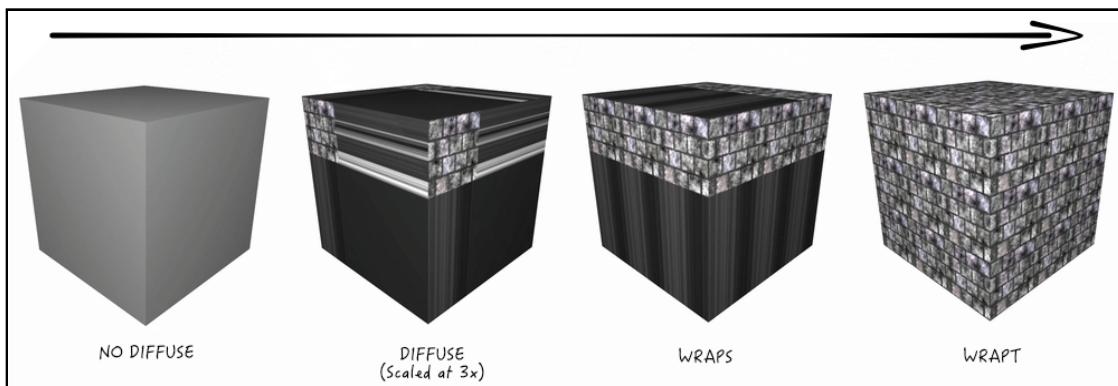
- **Diffuse:** Select the diffuse map; the pattern tries to fill the whole block. Since it's such a large block, you need to scale it the texture down to fit the perspective of the smaller stone block.
- **Scale:** Adjust the scaling factor to **(x:3, y:3, z:3)**, which scales down the texture — but to one corner only. To let it fill the block, you have to tell the pattern to repeat.

- **WrapS:** Set wrapS to **repeat**, which enables horizontal texture wrapping; suddenly the texture pattern repeats horizontally.
- **WrapT:** Set wrapT to **repeat**, which enables vertical texture wrapping; the texture pattern repeats vertically and fills the entire block.

Here's how your Materials Inspector will look when you're done:



Here's the end result of each step in succession:



You can use some of these same techniques to solve the 1x3 pillar as well.

Where to go from here?

This brings you to the end of this chapter. Your game is coming along nicely — great job!

Here's a quick recap of what you learned in this chapter:

- **Reference Nodes:** A reference node is basically a scene all on its own with its own set of objects. The reference part comes in when you've re-used that scene within another scene. Any changes made to the original referenced scene will automatically change all the referenced nodes.
- **Mip Map Filtering:** Mip mapping can make your game look better *and* perform better too.
- **Texture Scaling & Wrapping:** Textures can be scaled, wrapped and repeated to fill in large areas.

In the next chapter, you'll use the objects you created in this chapter to build little mini sets, which you will ultimately reference when you build your main game scene.

13

Chapter 13: Shadows

Chris Language

Getting started

If you suffer from sciophobia, then this chapter's going to be a bit of a challenge for you — but if not, you've got this one in the bag. This chapter deals with a very dark subject matter — shadows! :]

One thing comic books have taught us all is that evil cannot exist without good. One villain in particular pointed this fact out in the movie *Unbreakable*; Mr. Glass knew that an arch-villain can only exist if there's a hero. Well the same goes for shadows — they can only exist in the presence of light.

You've already learned about all the different types of light sources available in SceneKit. Unfortunately, not all lights are capable of casting shadows; only the **spot** and the **directional** lights have this *dark* ability.

Shadows

In order to demonstrate how lights and shadows work, we had to fabricate a sample scenario, leading you to this very important question:  *Do You Want to Build a Snowman?*  :]



The neighborhood kids built this little guy on your front lawn, and now he's casting a shadow thanks to the directional light that's simulating sunlight. How sweet; now go grab a shovel and show Olaf's distant cousin what you think about little kids' art projects on your property! :]

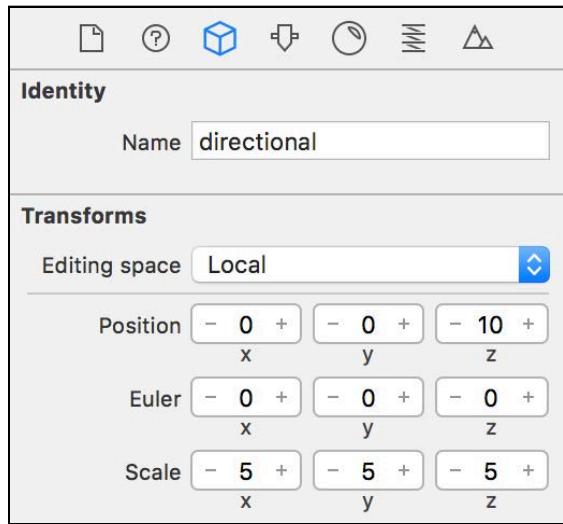
Directional shadows

You know how a laser shines a thin beam of light into the distance? You can think of a directional light as a million little laser lights, streaming light in parallel in a given direction.

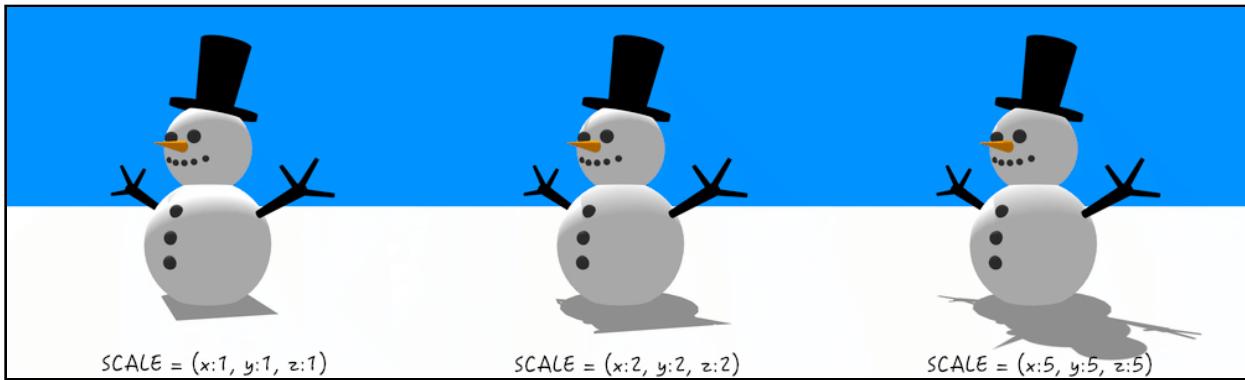
Unlike a spot light shadow, the size of the shadow cast by the directional light won't change as the distance to the light source changes. However, the length of the shadow is affected by the angle at which the light hits the 3D object, just as your shadow grows longer towards sunset.

Directional lights are somewhat strange when it comes to casting shadows, because the node's scale property plays a big part in determining the area of the shadow it creates. SceneKit creates a 2D shadow map from the light node's point of view. Directional lights ignores position information because the light has a constant direction. Directional lights require an orthographic projection. That's why the scale property controls the visible extents of the orthographic projection.

If you're using a directional light in your scene and you don't see a shadow, you probably need to adjust the node's scale. This can be done by either tweaking the node scale, or the light shadow attribute's scale:



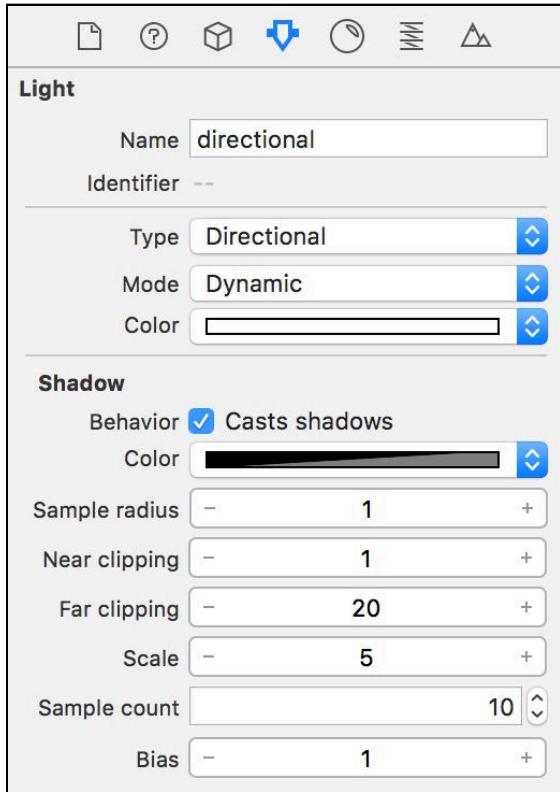
The image below demonstrates the effect that adjusting the directional light's node scale has on the resulting shadow:



At a scale of 1, you can clearly see a square shadow that's clipped in both the x and y directions. As you increase the scaling to 2, you start to notice the shadow of the rounded body, but still no hands, nose or head. Finally by increasing the scale to 5, you're able to see all the body parts, even the pointy nose.

Note: For a more hands-on experience, have a look under the **resources/Snowman** folder. Double click the **Snowman_Directional.scn** scene file to open it up in Xcode. Select the **directional** light under the scene graph, then press ⌘4 (Option+Command+4) to open up the attributes inspector.

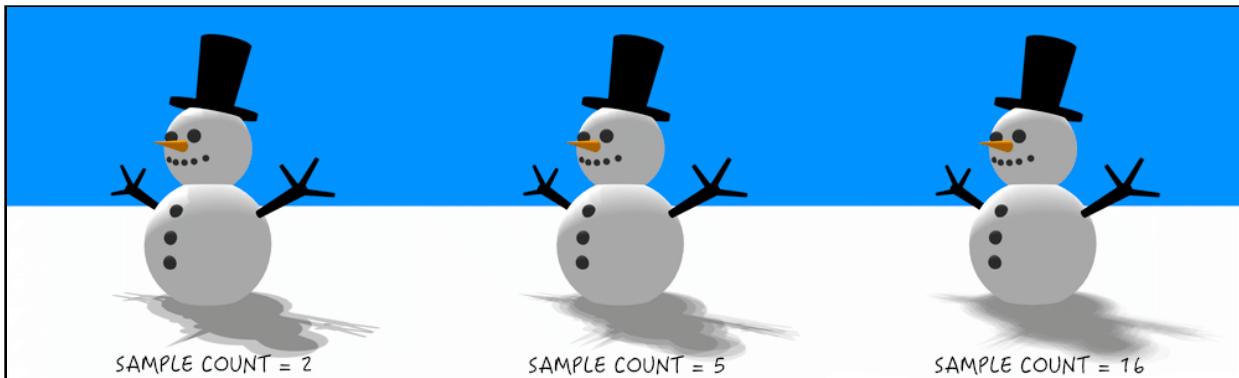
Take a closer look at the directional light's Attributes Inspector; you'll notice there's a **shadow** section at the bottom:



Iterating through all the available shadow properties:

- **Behavior:** Determines whether the light will cast a shadow.
- **Color:** Determines the color of the shadow cast. You can modify the color and transparency level; this lets other colors show through the shadow.
- **Sample radius:** SceneKit can produce soft shadows by rendering a silhouette of your 3D object onto a 2D shadow map; this radius is used to generate several sample shadow maps. A lower radius will result in a sharper shadow, while larger radii will produce softer shadows.
- **Near/Far clipping:** Any object outside the range of these values from the light source will not produce a shadow, thus clipping its own shadow. This property can be tweaked when performance starts to become an issue.
- **Scale:** Determines the resolution of the generated shadow maps. A scale of 1 will produce the highest resolution, while higher values produce lower-resolution shadow maps.
- **Sample count:** This property works hand-in-hand with the sample radius property. Specifying higher numbers produces softer shadows.
- **Bias:** Sometimes rendered shadows might not render onto all pixels as expected, causing an effect known as *shadow acne*. You can use this property to fix those types of artifacts.

The image below shows the effect of adjusting the shadow sample count on a spotlight shadow with a fairly large sample radius:



With a sample count of 2, you can see two distinct shadows produced. Pushing the sample count higher produces more shadow samples, and eventually ends with a soft shadow on the far right.

The next image shows the impact of shadow scale and reducing the generated shadow map resolution:



With a resolution of 1, you can see a nice crisp shadow edge. Pushing the shadow map resolution lower produces blockier and blockier shadows.

Note: Finding the sweet spot between the shadow Scale and Sample Count plays an important part in tweaking the performance of your games. Crisper shadows are less processor-hungry than soft, smooth shadows. Keep that in mind when you're trying to manage performance issues in your game.

Spot shadows

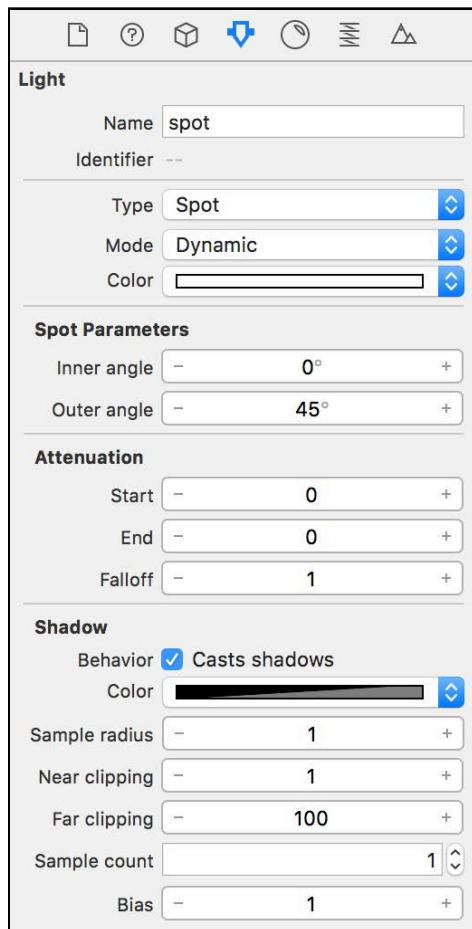
Arkham City is in trouble; mass riots have broken out, pushing the police force to the breaking point. Arkham has only one hope left — signal the Batman! :]

The Batman signal is a good example of a spot light that casts a shadow. The closer the object is to the light source, the bigger the shadow it casts due to the cone structure of the spot light.

Let's return to Olaf's distant cousin for a moment. Night has fallen upon Winter Wonderland, and a nearby street light now shines its light onto the little snowman, casting a shadow in front of it.

Note: For a more hands-on experience, have a look under the **resources/Snowman** folder. Double click the **Snowman_Spot.scn** scene file to open it up in Xcode. Select the **spot** light under the scene graph, then press ⌘4 (Option+Command+4) to open up the Attributes Inspector.

Take a look at the spot light's Attributes Inspector; you'll notice a **shadow** section at the bottom:



The options for spot lights are similar to the options for directional lights:

- **Behavior:** Determines whether the light will cast a shadow or not.
- **Color:** The color of the cast shadow. You can choose both color and transparency level, this will allow the shadow to allow other colors through.
- **Sample radius:** Scene Kit can produce soft shadows by rendering a silhouette of your 3D object onto a 2D shadow map, this radius is then used to generate several sample shadow maps. A lower radius will result in a sharper shadow, where larger radii will produce softer shadows, at the expense of performance.
- **Near/Far clipping:** Any object not within the range of these values from the light source will not produce a shadow, thus clipping their shadows. This property can be tweaked when performance starts to become an issue.
- **Sample count:** This property works hand in hand with the sample radius property. Specifying how many shadow samples to generate when generating the shadow map. Higher numbers should produce softer shadows.
- **Bias:** Sometimes rendered shadows might not render onto all pixels as expected, causing an effect known as shadow acne. You can use this property to fix those types of artifacts.

The image below shows the effect of adjusting the sample count of the spotlight shadow with a fairly large sample radius:



A sample count of 1 creates a crisp, clean and sharp shadow. With a sample count of 2, you can clearly see two distinct shadows, as if the shadows were produced from two light sources that are close in proximity. Pushing the sample count up to 5 produces a softer, smoother shadow.

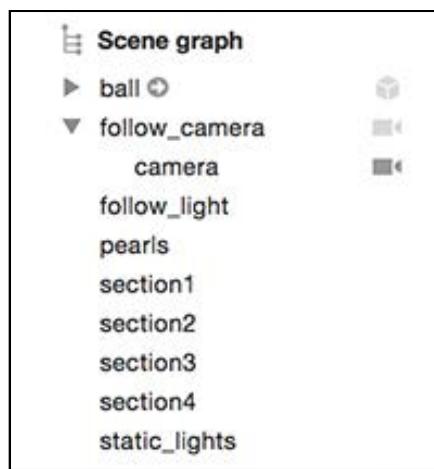
OK that's it for your snowman — time to add some shadows to Marble Maze using what you've learned so far!

Note: Before you continue, open the starter project under the **projects/starter/MarbleMaze** folder. It continues where you left off with the previous chapter.

Organizing the scene

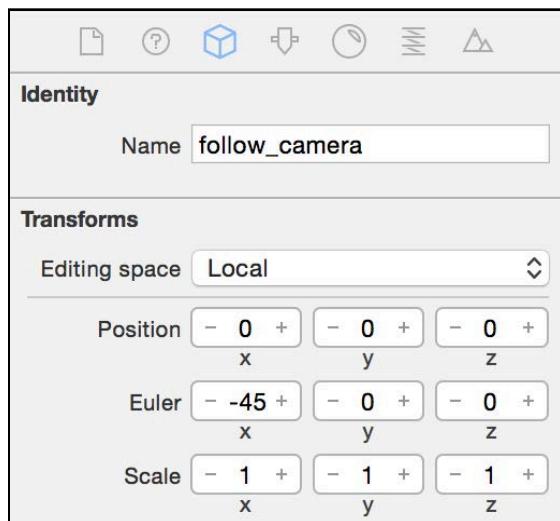
At this point, you need to do some basic housekeeping on the main game scene.

Select the **art.scnassets/game scn** scene. You should already have a ball and a camera node in the scene. You're going to organize the scene graph so it looks like the following:



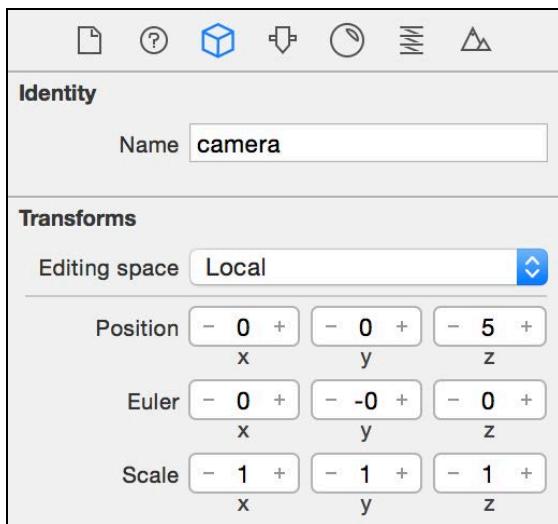
You'll deal with the scene graph first.

Create an empty node named **follow_camera**:



Zero out its position and set its rotation angle to (x:-45, y:0, z:0).

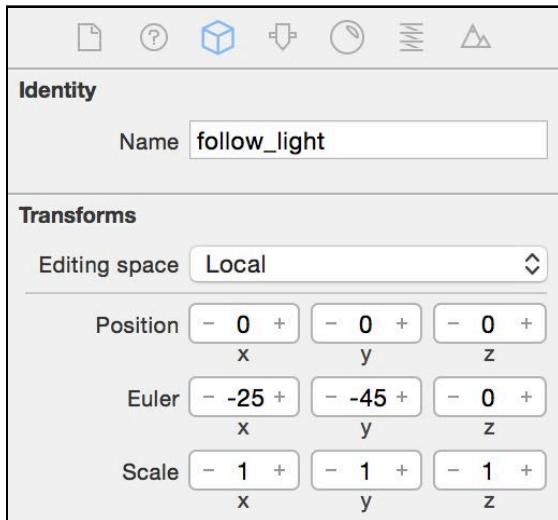
Make the **camera** node a child of **follow_camera**:



Set the **camera** position to (x:0, y:0, z:5), and ensure the rotation angle is reset to (x:0, y:0, z:0)

Note: By making the **camera** a child node of the **follow_camera** node and placing it at a z-position of 5 units, you have essentially placed it on an imaginary selfie stick. If you move the parent node position, the **camera** will simply follow. If you rotate the parent node, the **camera** will swing around, but it will always face the parent position — it's a neat little trick. Selfie time! :]

Create another empty node named **follow_light**:



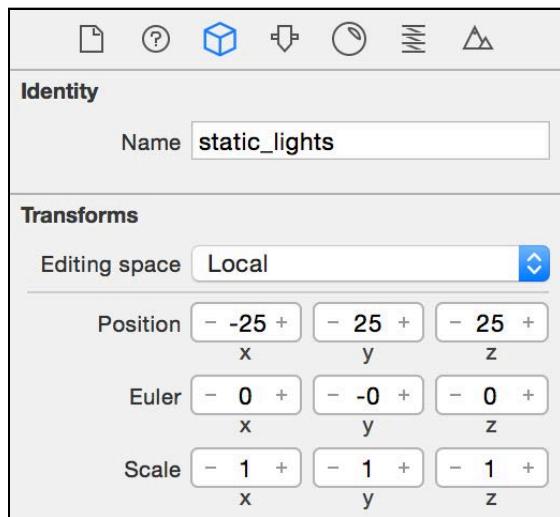
Zero out its position as well. You'll add a spot light to this node that always shines light on its subject. Set the node's rotation to (x:-25, y:-45, z:0). Spin the scene

around and you'll notice the background source of light comes from that precise direction.

Add the following empty nodes and zero out their positions; they're simply placeholders for later:

- **pearls:** You'll add collectible pearls under this group.
- **section1, section2, section3, section4:** These groups will hold different sections of the level. This will also help you hide certain sections to simplify level editing.

Create a final empty node and name it **static_lights**:



Set its position to ($x:-25$, $y:25$, $z:25$); you'll use this node to group additional lights.

You're all organized and ready to carry on.

Lighting

You're going to add some static lights to the scene; these are lights that don't move around. You'll also add a spot light to the scene which will move around, following the relic as it rolls through the maze. This spot light will also cast the shadows in your scene.

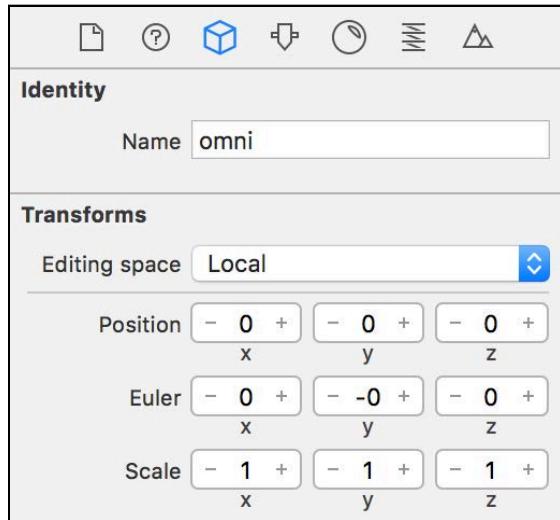
Adding static lights

First, you'll add the static lights to the scene. The purpose of these lights is to give the scene some basic lighting, break up the darkness a little and help those normal maps pop.

Drag and drop an omni and an ambient light into the scene and place them under the **static_lights** group node:

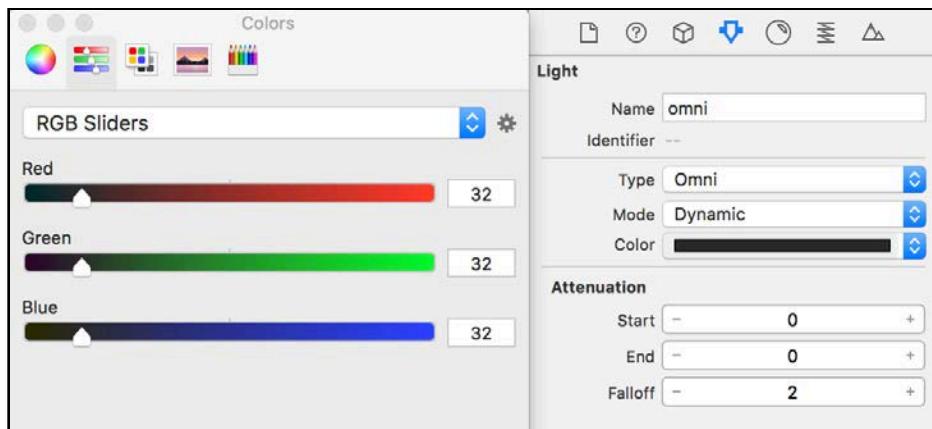


Select the omni light, then select its Node Inspector:



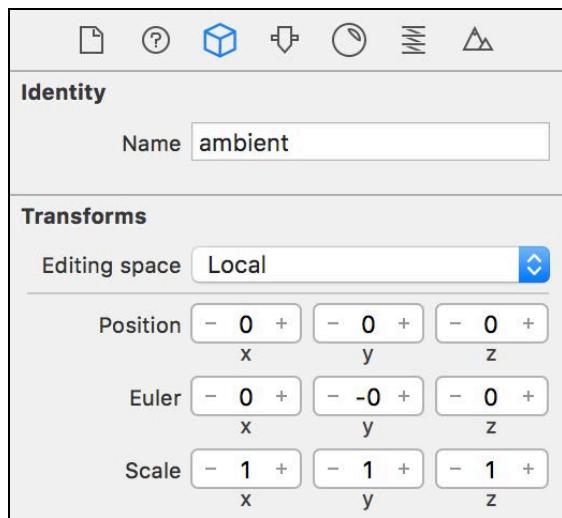
Name the light **omni** and zero out its position and angle; this will place the light right in the middle of its parent node.

Select the Attributes Inspector next:



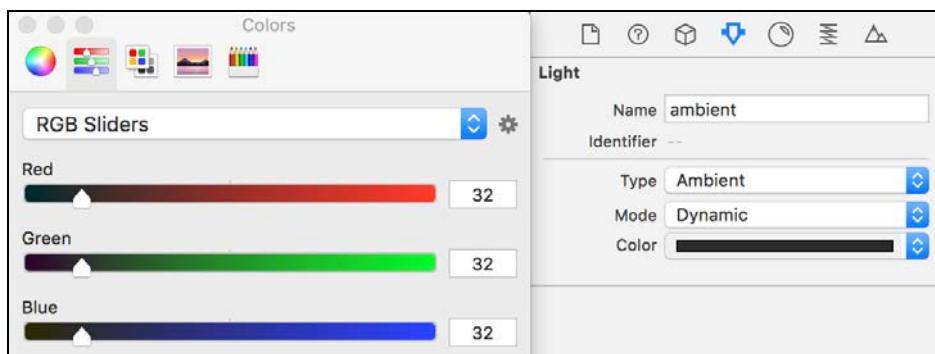
Give the omni light a dark grey color, so that it's not too bright but still has a visible effect.

Select the ambient light next, then select its node inspector.



Zero out its position and angle information, which places it right on top of the **omni** light, inside the **static_light** group node parent.

Select its Attributes Inspector:



It might seem odd, but give the ambient light a dark grey color as well to lift those dark shadows up a bit.

The final result should resemble the following scene, if you zoom in a bit closer to the ball:



You should be able to see the normal map, and the dark side of the relic shouldn't be black, but softly shaded.

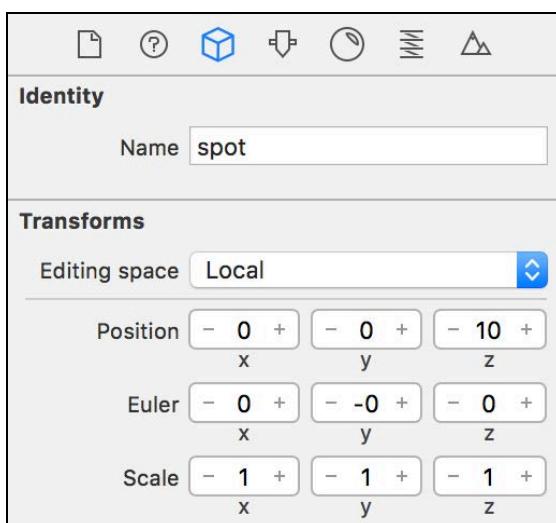
Now to add the light that will follow the relic as it rolls around the scene.

Adding a follow light

Drag and drop a spot light into the scene, and place it under the **follow_light** group node:



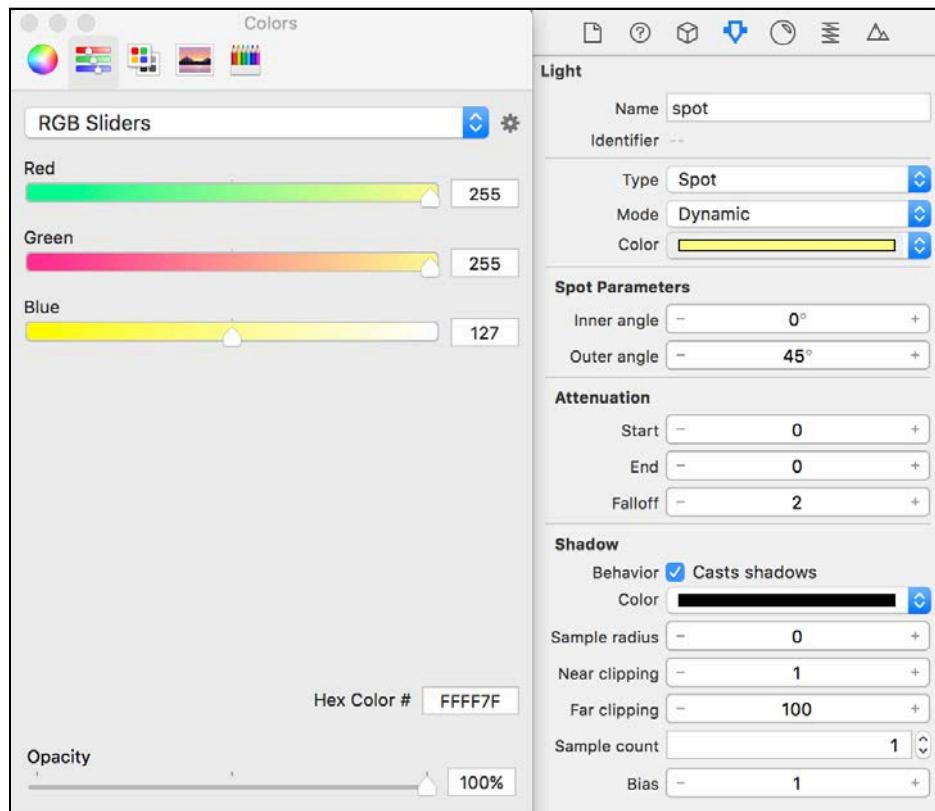
Select the spot light and then select its Node Inspector:



Name the light **spot** and set its position to (x:0, y:0, z:10). This light is a child of the **follow_light** group node, which is at (x:0, y:0, z:0) with a angle of (x:-25, y:-45, z:0); therefore the spot light will shine directly on the relic.

Note: This is the selfie stick trick in action, making your life so much easier. To keep the light shining on the rolling relic, you simply need to make sure the position of the **follow_light** node matches that of the relic.

Now to add some light and shadow magic. Select the spot light, then select its Attributes Inspector:



First, set the color of the light to a nice bright golden yellow. This will breathe some warmth into the light and mimic the environmental sunlight shining on the relic.

For a hard-edged shadow, enable **Behavior** so that the light casts shadows. Set **Sample Radius** to 0 to get a crisp shadow. You can leave Near and Far Clipping as they are. Set **Sample Count** to 1 so that you sample the shadow at least once, and leave **Bias** at 1.

Your scene should now resemble the following:



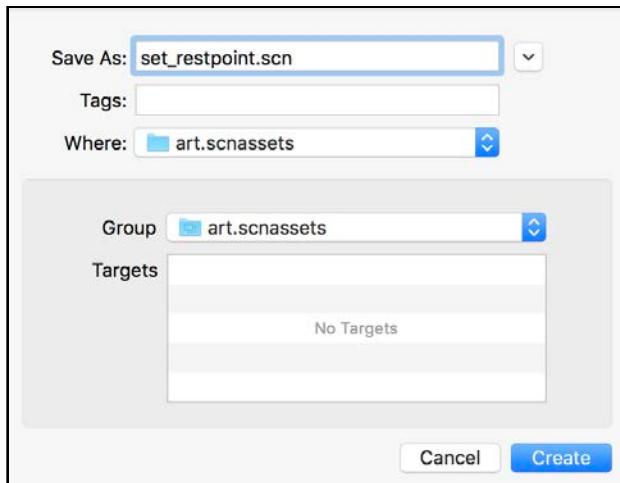
Behold the glorious golden sun shining warmth onto the relic! :]

Re-usable sets

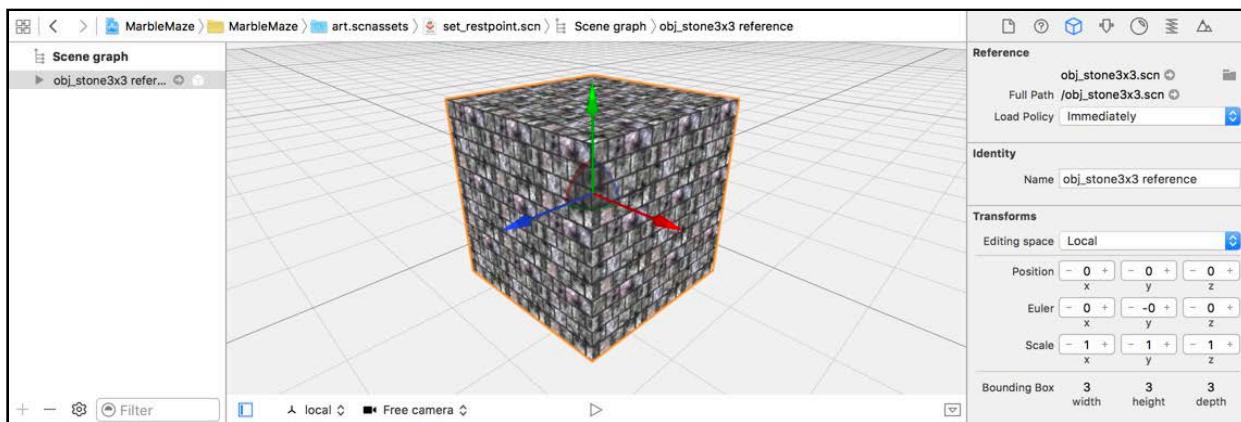
Building small little re-usable sets will make your life easier. This way you don't have to manually repeat common patterns and structures, you simply re-use the set where you need it in the level.

In this section, you'll create a resting point for the relic. It will consist of a nice big 3x3 stone, with 4 pillars stacked on top of it.

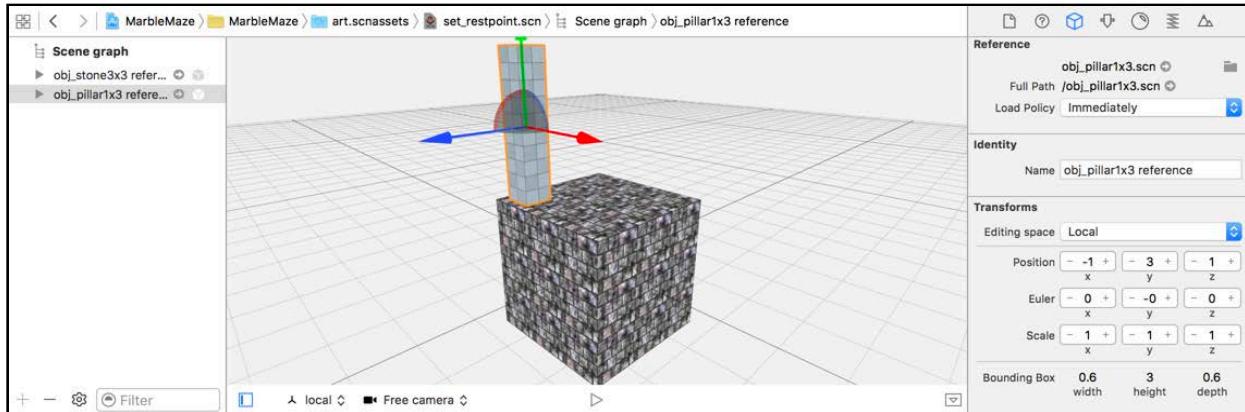
Drag an empty **SceneKit** scene file, from the **File Template** library into the root of your project. Name it **set_restopoint.scn**, then select the group as **art.scnassets** before you hit the **Create** button.



Drag and drop an **obj_stone3x3.scn** reference node into your new empty scene. Make sure to position it at (x: 0, y: 0, z:0).

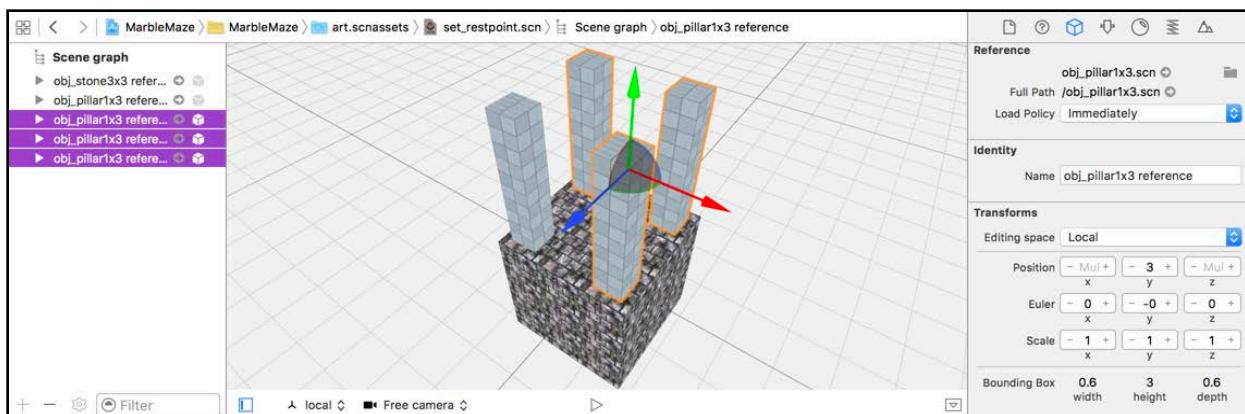


Drag and drop an **obj_pillar1x3.scn** reference node on top of the big stone. Set the position to (x: -1, y: 3, z: 1), so place it right in the corner.



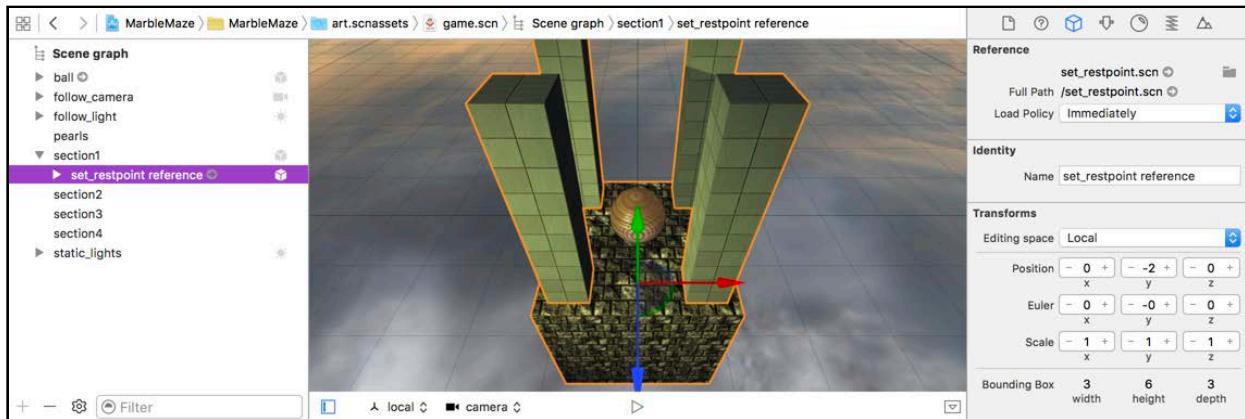
With one pillar down, you still need to create 3 more. Use the ⌘ (Option +Command) key combination to drag copies and place them precisely at the following locations:

- **Top-Left.** Positioned at (x: -1, y: 3, z: -1).
- **Top-Right.** Positioned at (x: 1, y: 3, z: -1).
- **Bottom-Right.** Positioned at (x: 1, y: 3, z: 1).



Note: Don't forget to delete that default camera node out of the reference scene before you save it.

Select your **game.scn**, then drag and drop that freshly built **set_restopoint.scn** below the relic. Make sure to position it at (x: 0, y: -2, z: 0)



Build and run your project, and admire those pretty shadows:



Behold the glorious golden sun with a soft cool shadow casted over the relic! :]

Note: You can find a project containing all the work done up to this point under the **projects/final/MarbleMaze** folder.

Challenge

Surprise challenge! You didn't see that one coming, did you? :]

Now that you've mastered the skill of using reference nodes and building small scenes and sets, you'll need to build some more basic sets, which will be referenced in the main game scene.

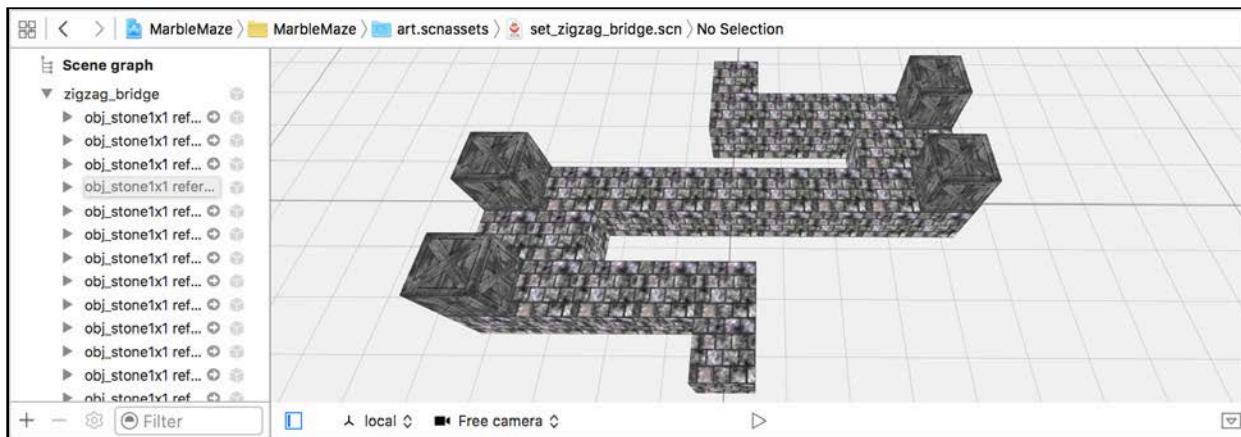
Build the following sets for the game, making use of the following samples:

The **straight_bridge**:



This set consists of seven small **stone1x1** blocks, all neatly packed next to each other.

The **zigzag_bridge**:

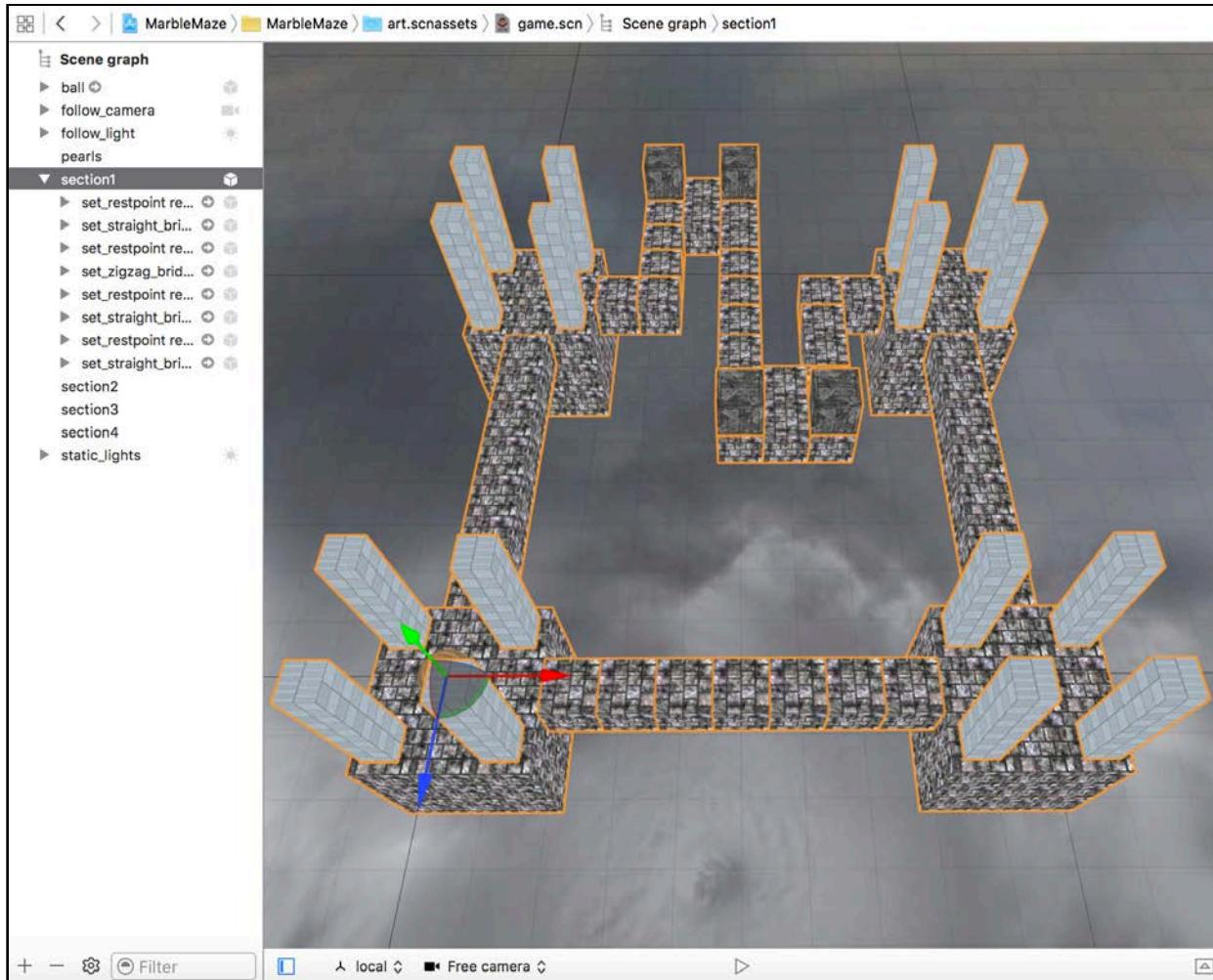


This set might be a bit trickier, but nothing's too tough for you now! :] It's constructed of **stone1x1** blocks and **crate1x1** blocks. It's 9 blocks wide and 7 blocks deep. Make sure to place those crates right on the corner edges.

Note: Each set starts with a blank scene, then uses reference nodes to build up the set. Remember to remove all lights and cameras from these sets as they'll be referenced in your main game scene.

Once you've created all those little sets, see if you can build the first section of the main game scene.

Here's a sample of what the final result should look like:



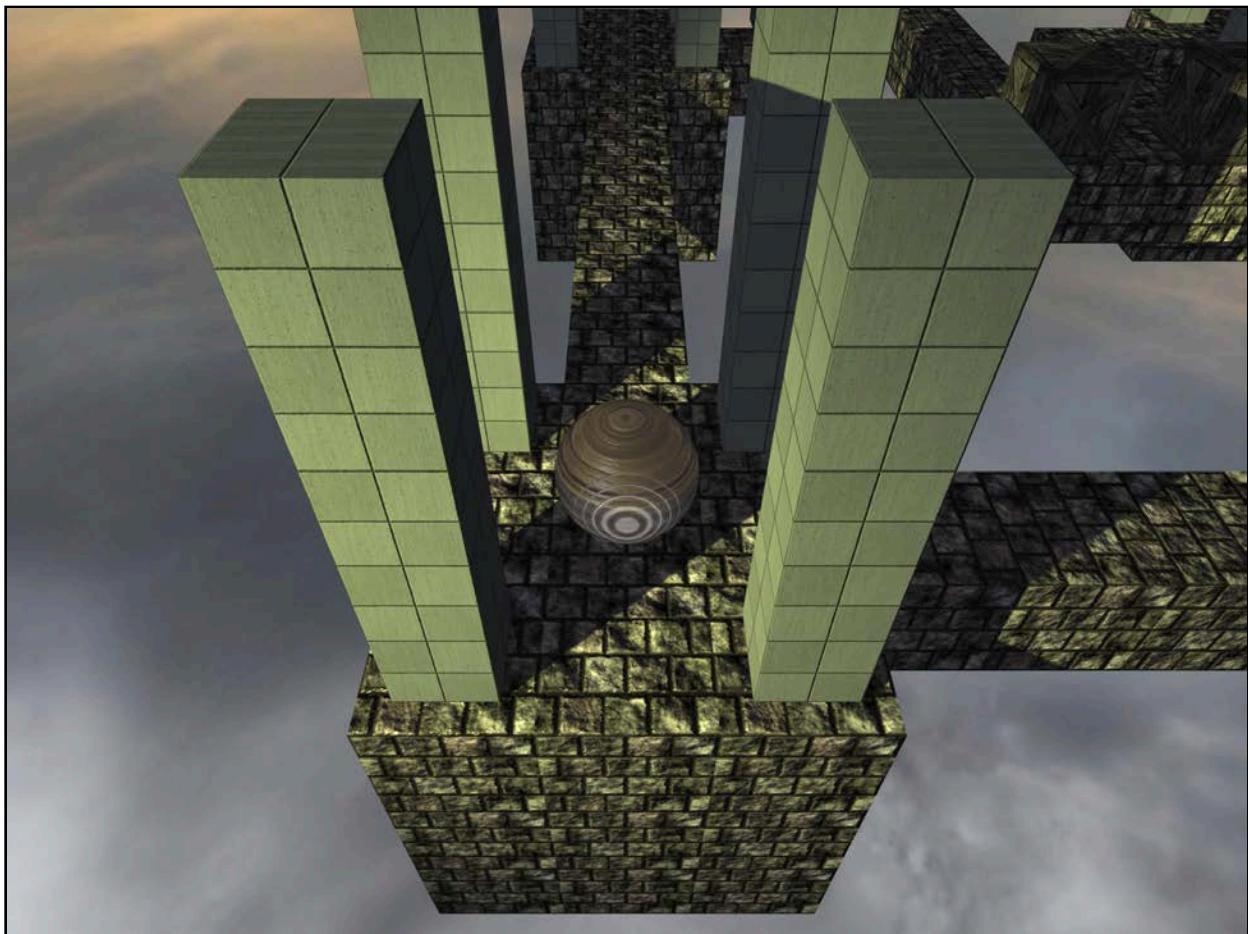
Start at the bottom left corner, place a **restpoint** right underneath the relic positioned at $(x:0, y:0, z:0)$, then pull in the rest of the reference sets to complete the entire scene.

Make sure you place all the sets under the **section1** group node. This is a neat little trick you can apply when you start building large scenes: simply segment the set into sections, then use the **visible** flag to show or hide the set as required. This will definitely speed up the editing process.

Note: Fear not, if this challenge pushed you out of your comfort zone, you can download the final project under the **projects/challenge/MarbleMaze** folder.

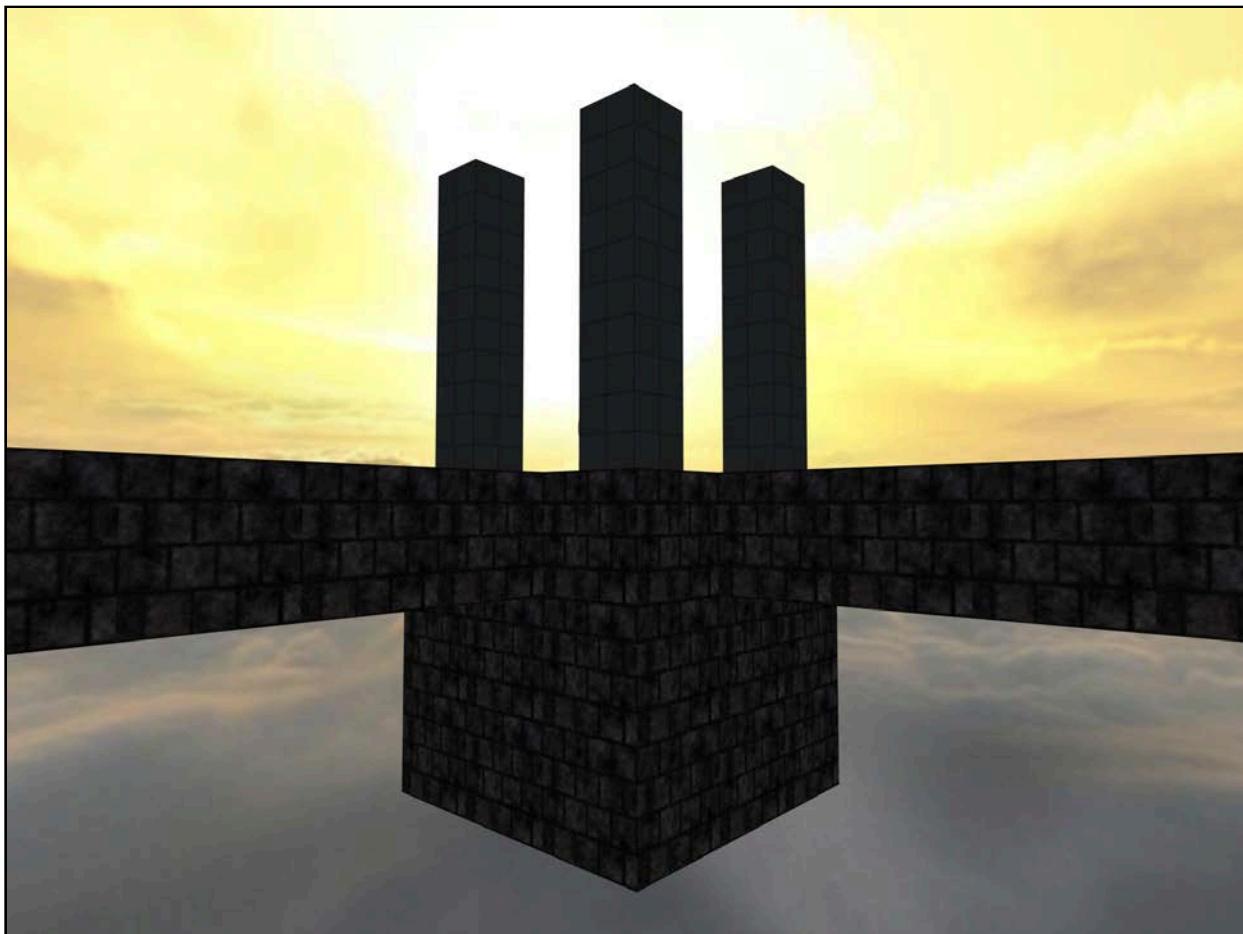
Finishing touches

To see the stunning result first-hand on a device, build and run and pan the camera around the scene. If you prefer, you can just press the **play** button under the scene:



Did your jaw bone just dislodge itself? :] It's an absolutely stunning view.

Before you continue, see if you can spin the view around so that you have the sun light shining in your eyes, like so:



Lights placed at strategic locations in your scene, along with your environmental map, make for some impressive realism. You almost want to squint your eyes, even though your screen can't go any brighter than white. It's all just an illusion — thanks to those stunning silhouetted pillars caused by the shadows.

Where to go from here?

You've reached the end of this chapter; your game is in good shape. In this chapter, you covered the following concepts:

- **Lights:** Shadows need lights; specifically, a spot light or a directional light when dealing with SceneKit.
- **Soft and hard shadows:** The shadow's Sample Radius and Sample Count settings have a definite effect on the hardness of the shadow edge.

The next chapter will make your game come alive and let your player take control of the relic, rolling it through your maze in the sky!

Chapter 14: Intermediate Collision Detection

Chris Language

Getting started

In this chapter, you'll enable physics within your game and add collision detection. For the most part, the player will roll the ball around the maze, bumping into stone blocks and crates, while trying to keep the ball from falling off the maze. Although rolling around on a sky maze is pretty cool, it's still lacking that *fun* factor — something that will force the player to take on the maze as fast as possible.

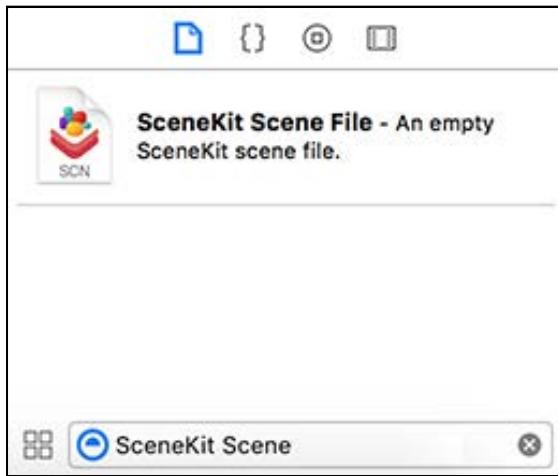
If nothing pushed the player to roll through the maze, then the player could simply park the ball in a corner and take a nap until they felt like tackling the next part of the maze. That's just not acceptable! :]

Therefore, the ball will have to consume pearls of life in order to survive. You'll use the rings of light on the ball as a visual indicator of how much life the player has left; the brighter the rings of light shine, the more life that's left in the ball. The player's life reduces over time, which forces the player to scout for more pearls of life scattered all over the sky maze.

Note: This chapter continues where the previous one left off; you can find the starter project for this chapter under the **projects/starter/MarbleMaze/** folder.

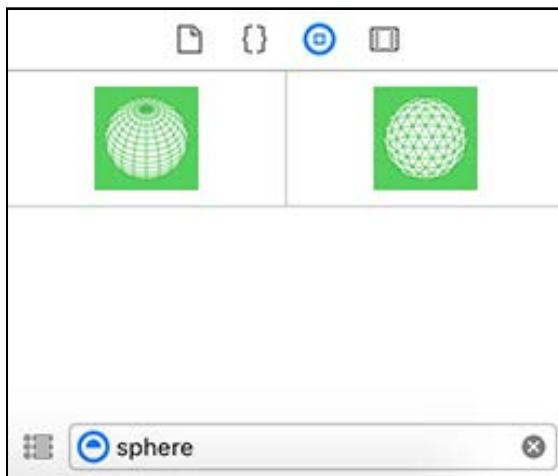
Setting up the SceneKit scene

Drag an empty SceneKit file into your project:

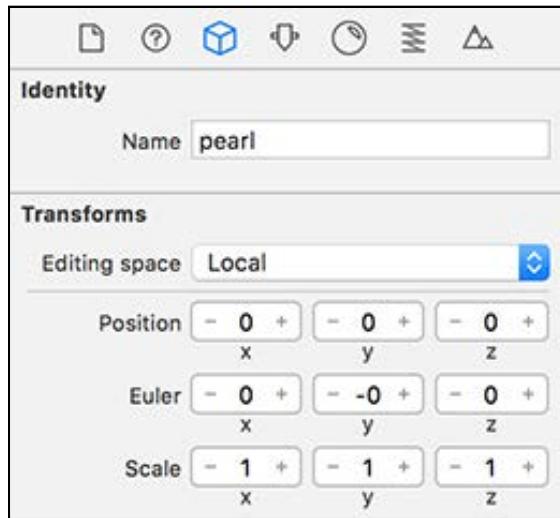


Name it **obj_pearl.scn** and save it to the **art.scnassets** folder. Remember to delete the default camera node; you don't want extra lights and cameras in reference nodes.

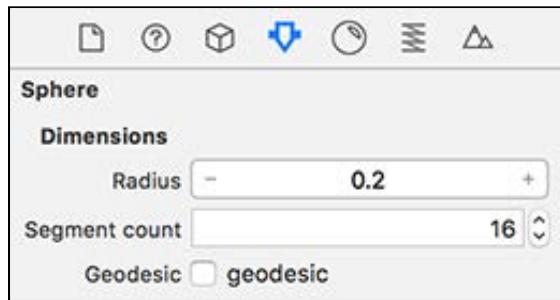
Next, drag and drop a sphere node from the Object Library into your new scene:



Use the Node Inspector to name the node **pearl** and zero out its position and angles:

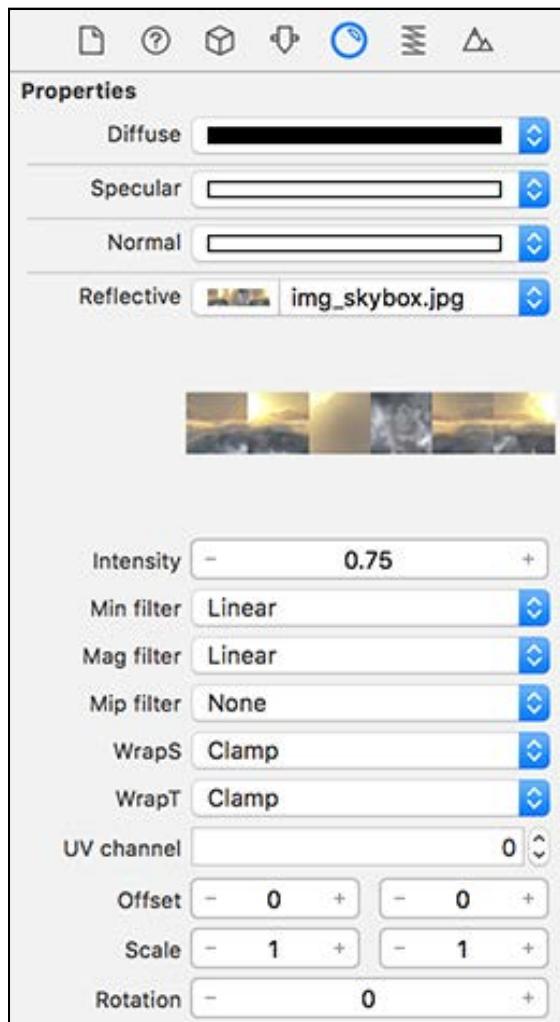


Use the Attributes Inspector to set the radius to `0.2` and reduce the segment count down to `16`:



This shrinks the pearl down to a consumable size. :] There's going to be plenty of pearls in the game, so keeping the polygon count low is important.

Your next task is to make the pearl shiny. Use the Materials Inspector to set the diffuse color to black, with a white specular. Pearls are very reflective, so use `img_skybox.jpg` as a reflective map, but drop the intensity down to `0.75`:



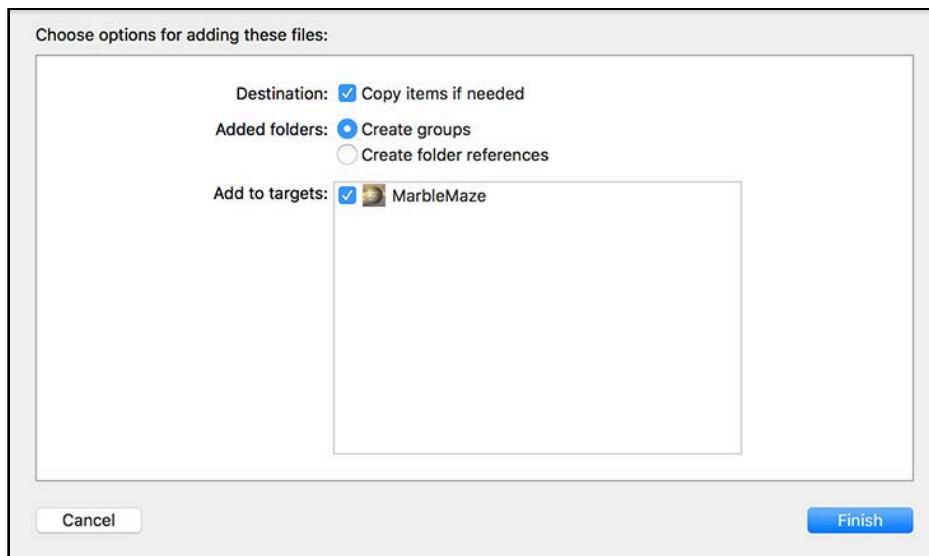
You'll end up with something that resembles this little golden nugget. Just look how shiny it is! :]



Game utilities

To keep you focused on collision detection, we've provided a bunch of game utilities for you matters outside the focus of this chapter, like some math utility functions, SpriteKit integration, and so on. All you need to do is add them to the project.

Drag and drop the **GameUtils** folder into your project from the **resources/GameUtils/** folder:



Select **Finish** to complete the process.

Now you'll need to handle the collisions between the ball and the pearls of life. Before you dive into that, you need to understand how bit masks work. The next section covers just that.

Bit-masks

Bits are those 1's and 0's computers use to represent numbers that looks like this: 00101011. A collection of 1's and 0's is known as a **binary** number. Each bit represents a specific numerical value and reads in reverse, from the lowest-significant bit to the highest-significant bit. If the bit is 1, it's considered ON, while 0 means it's OFF.

Below is crude example of an 8-bit binary value, counting up from zero to seven:

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | INTEGER VALUE |
|-------|-----|----|----|----|---|---|---|---|-----------------------|
| VALUE | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| 1. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | $0+0+0+0+0+0+0+0+1=1$ |
| 2. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | $0+0+0+0+0+0+0+2+0=2$ |
| 3. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | $0+0+0+0+0+0+0+2+1=3$ |
| 4. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | $0+0+0+0+0+0+4+0+0=4$ |
| 5. | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | $0+0+0+0+0+0+4+0+1=5$ |
| 6. | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | $0+0+0+0+0+0+4+2+0=6$ |
| 7. | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | $0+0+0+0+0+0+4+2+1=7$ |

The first row represents the bit index (7 to 0) and counts starting on the right. The next row shows the value each bit represents. The last column adds all the represented values together for the bits that are ON. For example, the binary value 01010101, where bits 0, 2, 4 and 6 are all ON and the rest are all OFF, represents the following calculation: $64 + 16 + 4 + 1 = 85$. So 01010101 is the binary representation of decimal 85. Easy!

Bit masks are binary numbers in disguise. Bit masking is a clever way of giving all objects in a physics simulation a low-level identity. You can then perform bitwise operations on your objects to quickly filter out which objects can collide with each other. This technique reduces the amount of objects involved when performing collision detection, hence speeding up the collision checking process quite a bit.

Category masks

The category mask gives an object a unique ID for collision detection. Besides giving an object a unique ID, you can also group objects together.

Consider *Pac-Man* as an example. There are lots of things Pac-Man can collide with; some good, and some bad. So you could create two groups, one for good things, and one for bad things — like ghosts!

Here are a few category bit mask examples you might see in a typical *Pac-Man* game:

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | INTEGER VALUE |
|--------|-----|----|----|----|---|---|---|---|---------------------------|
| VALUE | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| Good | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | $0+1+0+0+0+0+0+0+0 = 64$ |
| Bad | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1+0+0+0+0+0+0+0+0 = 128$ |
| Blinky | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | $1+0+0+0+0+0+0+0+1 = 129$ |
| Pinky | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | $1+0+0+0+0+0+0+2+0 = 130$ |
| Inky | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | $1+0+0+0+0+0+4+0+0 = 132$ |
| Clyde | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | $1+0+0+0+8+0+0+0 = 136$ |
| Blue | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | $0+1+0+0+0+0+0+0+1 = 65$ |

Here, the 8th bit is set to 1 to indicate membership in the **Bad** group, and since all the ghosts (Blinky, Pinky, Inky and Clyde) have the 8th bit set, they can be tested for "Badness" in a bitwise check.

For example, you could have a collision test to determine what exactly should happen to Pac-Man when he collides with an object, like the following:

```
// 1
let good = 64
let bad = 128
let blinky = 129
let pinky = 130
let inky = 132
let clyde = 136
let Blue = 65

func testCollision(contactNode:Int) {
    // 2
    if contactNode & bad == bad {
        // Bad things happens to Pacman
    } else if contactNode & good == good {
        // Good things happens to Pacman
    }
}
```

Taking a closer look:

1. This defines all the category masks as depicted in the table above.
2. This uses the bitwise `&` operator against the `contactNode` to filter out all the other bits. If the result matches `bad`, it means that the `bad` bit was set, which means `contactNode` is a bad guy, and Pac-Man has to die. :[

Since the contactNode for each of the ghosts in *Pac-Man* has the 8th bit set, it will always match the **bad** category mask in a bitwise & test.

Defining category masks

Marble Maze is a bit simpler than *Pac-Man*; it will use the following set of category masks:

| CATEGORY MASK | | | | | | | | | |
|---------------|-----|----|----|----|---|---|---|---|-----------------|
| BIT VALUE | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | OBJECT VALUE |
| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| AIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BALL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| STONE | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| PILLAR | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| CRATE | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| PEARL | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 16 |

All the objects have been defined with their own unique ID, so there's no need to worry about groups in this case. Your next task is to define these category masks somewhere.

Open **GameViewController.swift** and add the following collision categories to the top of the class:

```
let CollisionCategoryBall = 1
let CollisionCategoryStone = 2
let CollisionCategoryPillar = 4
let CollisionCategoryCrate = 8
let CollisionCategoryPearl = 16
```

Collision masks

You use collision masks to tell the physics engine that some objects are allowed to collide with each other; the physics engine will then prevent these objects from

simply passing through each other and trigger an effect within the dynamics of the physics engine. To define a collision mask, you'll need to add together all the category masks of objects that collide with your object.

For Marble Maze, you want the ball to collide with everything except for the pearls — you don't want the ball to push the pearls out of the way! Conversely, you'll also need to set everything, except for the pearls, to collide with the ball.

You can use the following collision mask table to keep track of things:

| COLLISION MASK | | | | | | | | | MASK VALUE |
|----------------|-----|----|----|----|---|---|---|---|---------------|
| BIT VALUE | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| AIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BALL | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 14 |
| STONE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| PILLAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| CRATE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| PEARL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Refer back to the category masks; you'll see the Stone, Pillar, Crate and Pearl collision masks are set to 1, which means they'll collide with the ball. To work out what the ball collision mask should be, you'll have to add all the other categories together to form the following calculation:

$$\text{CollisionMask} = \text{Stone} + \text{Pillar} + \text{Crate} = 2 + 4 + 8 = 14$$

Aha — that's why the ball collision mask is set to **14**.

Contact masks

Contact masks tell the physics engine which objects will generate contact events that you'll respond to. These won't automatically have any effect on the physics engine dynamics; they're triggers to which you'll respond programmatically. You set up contact masks in exactly the same way as you do collision masks.

For Marble Maze, you want the pearl to generate a contact event, but you also want the pillars and crates to generate an event so you can play a “bump” sound when the ball hits them.

You can use the following contact mask table for that:

| CONTACT MASK | | | | | | | | | |
|--------------|-----|----|----|----|---|---|---|---|---------------|
| BIT VALUE | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | MASK VALUE |
| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
| AIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BALL | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 28 |
| STONE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PILLAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CRATE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PEARL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

You’re only interested in contact between the ball and pearls, pillars and crates. This gives you the following calculation:

$$\text{ContactMask} = \text{Pearl} + \text{Pillar} + \text{Crate} = 16 + 8 + 4 = 28$$

Now you can configure the contact mask for the ball in your code.

Still in **GameViewController.swift**, add the following property to the top of the class:

```
var ballNode: SCNNode!
```

Now add the following code to `setupNodes()`:

```
ballNode = scnScene.rootNode.childNode(withName: "ball", recursively: true)!
ballNode.physicsBody?.contactTestBitMask = CollisionCategoryPillar | CollisionCategoryCrate | CollisionCategoryPearl
```

The first line attaches `ballNode` to the actual `ball` node in the scene. The next line sets up the actual `contactTestBitMask` by performing a bitwise OR on all category masks.

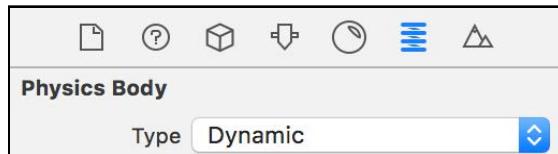
Note: You can set the category mask and collision mask in the Scene Editor, but at the time of writing this chapter you can only set the `contactTestBitMask` in code, hence why you are doing it here. Another benefit of setting it in code is it's easier to work with OR'ing constant values than having to remember what 28 represents in binary!

Now that you've figured out all the bit mask properties for all the game objects, you can enable the physics properties of those objects.

Enabling physics

The ball will be a *dynamic* physics body; this means the physics engine will take full control over the movement of the ball and move it based on its physics properties.

Select the `obj_ball.scn` scene under the `art.scnassets` folder, then select the `ball` node. Use the Physics Inspector to set the **Physics Body** type to **Dynamic**:



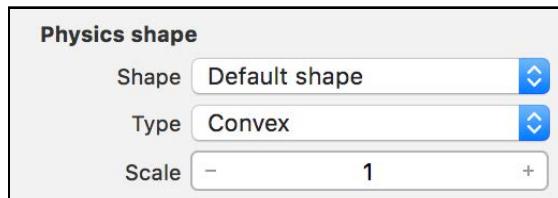
Ensure that **Gravity** is **enabled**; otherwise, the ball would float in space:



Now you can set up the bit masks. Set the **Category mask** to 1 and the **Collision mask** to 14:



You're going to leave the **Shape** at **Default shape**, and **Type** at **Convex**:



Since this is a spherical object, SceneKit sets it up as a perfect sphere instead of generating a mesh to represent the shape of the object.

Save the scene changes before you move on.

Return to your main game scene — **game.scn** under **art.scnassets**. Press the **play** button for the scene, and...the ball falls through the stone floor! Don't worry — this is because you haven't set up any of the other physics bodies yet.

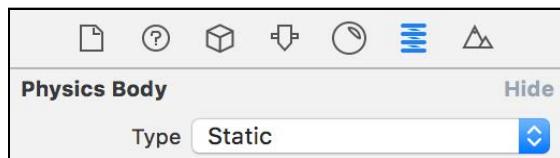
Enabling static physics objects

The rest of the objects in the game will be *static* objects, which means they can't be moved.

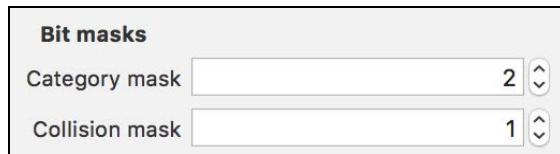
You'll need to repeat the following steps for all of these objects:

- obj_stone1x1.scn
- obj_stone3x3.scn
- obj_pillar1x3.scn
- obj_crate1x1.scn
- obj_pearl.scn

First, select the scene under the **art.scnassets** folder, then make sure the object node itself is selected. Use the Physics Inspector of each object to set their respective **Physics Type** to **Static**:



Now for the bit masks. Set the **obj_stone1x1.scn Category mask** to 2, and the **Collision mask** to 1:

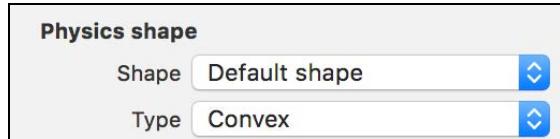


Configure the rest of the objects as follows:

- **obj_stone3x3.scn**: **Category mask** to 2, and **Collision mask** to 1.
- **obj_pillar1x3.scn**: **Category mask** to 4, and **Collision mask** to 1.
- **obj_crate1x1.scn**: **Category mask** to 8, and **Collision mask** to 1.
- **obj_pearl.scn**: **Category mask** to 16, and **Collision mask** to -1.

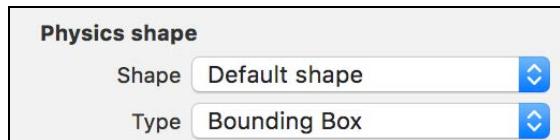
Note: The pearl is special, and will not cause an actual collision with the ball. That's why it's set to -1.

You're almost done — the only thing left is to configure the physics shapes. The pearl uses a Physics shape of **Default shape**, with a Type of **Convex**:



Since the pearl is a sphere, SceneKit will generate the physics shape as a perfect sphere.

The rest of the objects should be configured as follows, with **Default shape** and **Bounding Box**:



This creates a perfect box around the edges of the object. Since all these bodies are square by nature, the bounding box will fit them perfectly.

Note: The sphere is the most efficient physics shape you can use. The second-most efficient? The bounding box type.

Adding collision detection

To complete the collision detection, you need to add the code that will handle the actual collision events.

Add the following code to the bottom of **GameViewController.swift**:

```
extension GameViewController : SCNPhysicsContactDelegate {
    func physicsWorld(_ world: SCNPhysicsWorld,
                      didBegin contact: SCNPhysicsContact) {
        // 1
        var contactNode:SCNNode!
        if contact.nodeA.name == "ball" {
            contactNode = contact.nodeB
        } else {
            contactNode = contact.nodeA
        }

        // 2
        if contactNode.physicsBody?.categoryBitMask ==
            CollisionCategoryPearl {
```

```
        contactNode.isHidden = true
        contactNode.runAction(
            SCNAction.waitForDurationThenRunBlock(
                duration: 30) { (node:SCNNode!) -> Void in
                    node.isHidden = false
                })
    }

    // 3
    if contactNode.physicsBody?.categoryBitMask ==
        CollisionCategoryPillar ||
        contactNode.physicsBody?.categoryBitMask ==
        CollisionCategoryCrate {
    }
}
```

This extends the `GameViewController` class with the `SCNPhysicsContactDelegate` protocol. Here's what goes on inside:

1. This is the nifty little trick you learned previously that lets you quickly determine the actual contact node. The `if` block sets `contactNode` to the node that collided with the ball.
2. This section tests to see if the `categoryBitMask` of `contactNode` matches that of `CollisionCategoryPearl`. If so, make the pearl invisible to make it look like the ball "consumed" the pearl. You'll spawn the pearl again after 30 seconds; this is just long enough for the ball to die if the player decides to stick around and wait for the pearl to re-spawn.
3. This section checks whether the ball bounced off of a pillar or off of a crate. This would make a great place to play a "bump" sound later on.

Your final step for this chapter is to ensure that the scene's physics world contact delegate knows that the `GameViewController` class is now responsible for handling these contact events.

Add the following to the bottom of `setupScene()`:

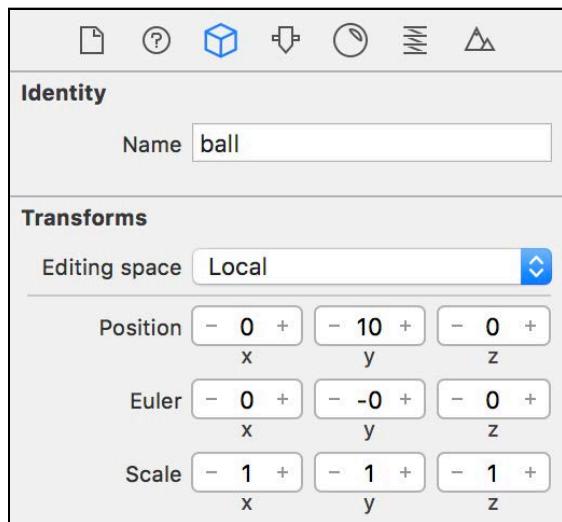
```
scnScene.physicsWorld.contactDelegate = self
```

Adding falling effects

There's one little thing you need to change, just to add some drama to your game.

Position the ball high up in the air, so that when the game starts, the ball will fall from the sky.

Open the `obj_ball.scn` scene, and select the `ball` node. Then adjust its `y` position to 10.



Build and run your game to make sure that everything is still well:

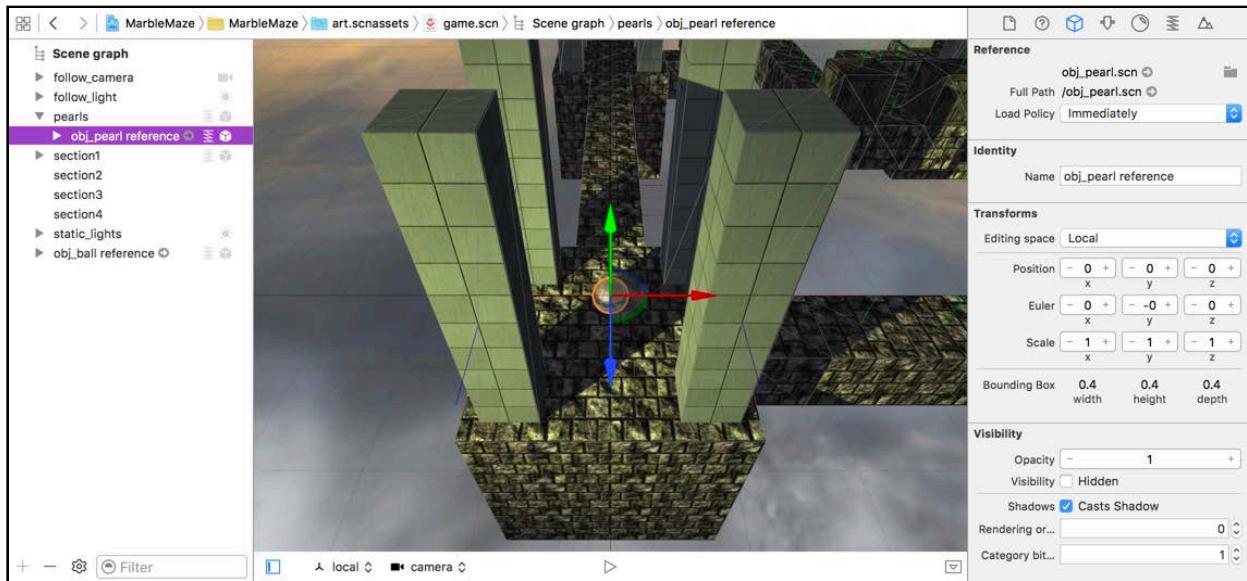


As the game starts up, you'll see the ball fall from above and come to rest on the stone platform below. Hey — it's not falling through the floor any more! Apart from that though, everything still looks pretty much the same as before.

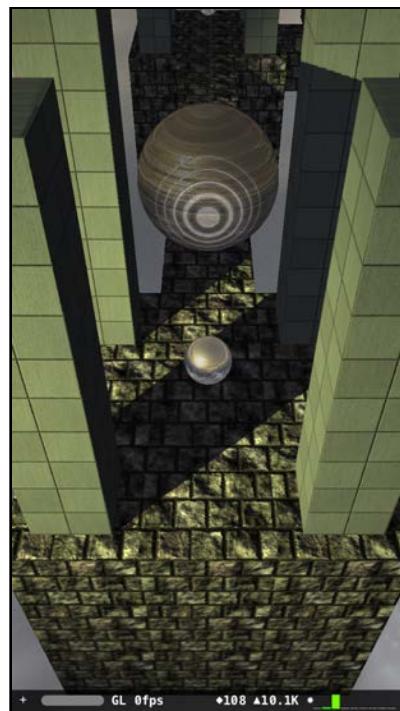
Adding pearls of life

Now to add something special to test out the collisions.

Select the game scene, then drag and drop a **obj_pearl.scn** reference node into the scene. Position it at (x: 0, y: 0, z: 0). Also make sure to move the pearl under the **pearls** group node.



Make sure everything is saved, then do another build and run:

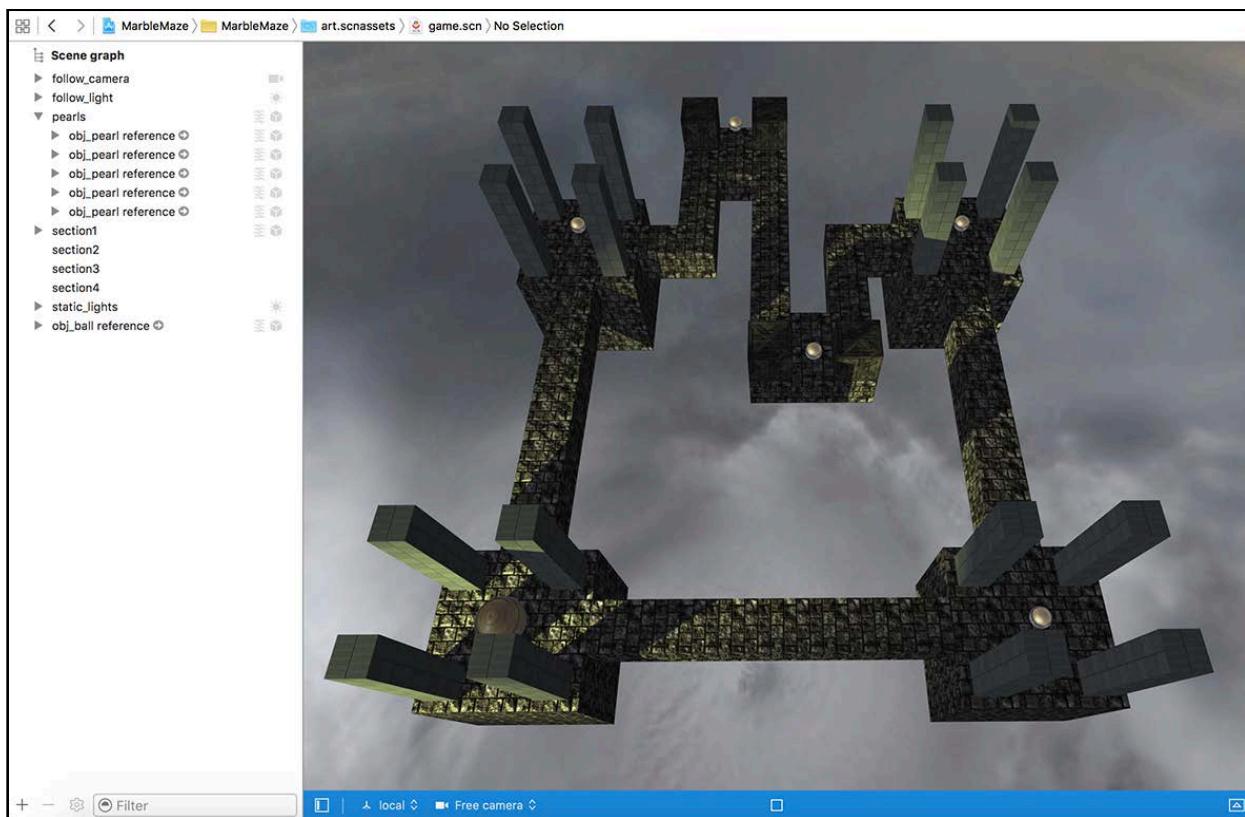


If you take a closer look, you should see the great relic falling from the sky, then gobbling up the pearl. Awesome! :]

Note: You can find the project up to this point under the **projects/final/MarbleMaze/** folder.

Challenge

Time for another fun little challenge; see if you can scatter a few more pearls for the player all over the level. You can use the following image as a reference:



Place a pearl on top of all the rest points and between all the crates. Make sure to place the pearls on a y position of 0 — the same plane as the relic. Also make sure you move all the pearls to the **pearls** group node to keep things nice and organized.

Note: You can find the solution for this challenge under the **projects/challenge/MarbleMaze/** folder.

Where to go from here?

You covered some complex topics in this chapter. To recap:

- **Collectibles:** You added a new element to your game to make it more interesting — the pearl of life. Without it, the ball would simply die a pathetic, lonely death. This also gives the player purpose to navigate the sky maze in search of more pearls.
- **Bit Masks:** You now know all about bit masks; what they look like, how they operate, and most importantly, how to use them in SceneKit.
- **Category masks:** You learned this mask simply gives the object an ID, and that you could employ complex grouping strategies should you need to.
- **Collision masks:** You learned this mask defines a list of objects that can collide with your object, and physically block them from passing through each other.
- **Contact masks:** You learned this mask defines a list of objects that will trigger contact events when they make contact with your object.

In the following and final chapter, you'll add the ability to move the ball. What are you waiting for? It's time to get the ball rolling! :]

Chapter 15: Motion Control

Chris Language

Getting started

Up to this point, you've focused mostly on the visual aspects of your game — and a fine-looking game it is! This chapter will make a detour from the aesthetics and take you through the code of the game mechanics.

First, you'll add a simple control mechanism to let the player move the ball by tilting the device. You'll then add some logic to the camera and lights to follow the ball wherever it wanders — even if it falls into the abyss! :] Finally, you'll add some basic state management, a HUD for the score, and finally finish it off with some awesome sound effects.

So what are you waiting for? Time to get cracking! :]

Game helpers

To start, either load the project where you left it off last time, or load the starter project under the **projects/starter/MarbleMaze/** folder.

In the previous chapter, you added the **GameUtils** folder from the resources. Now you need to declare a few variables so you can use those utilities.

Add the following properties to the top of the GameViewController class:

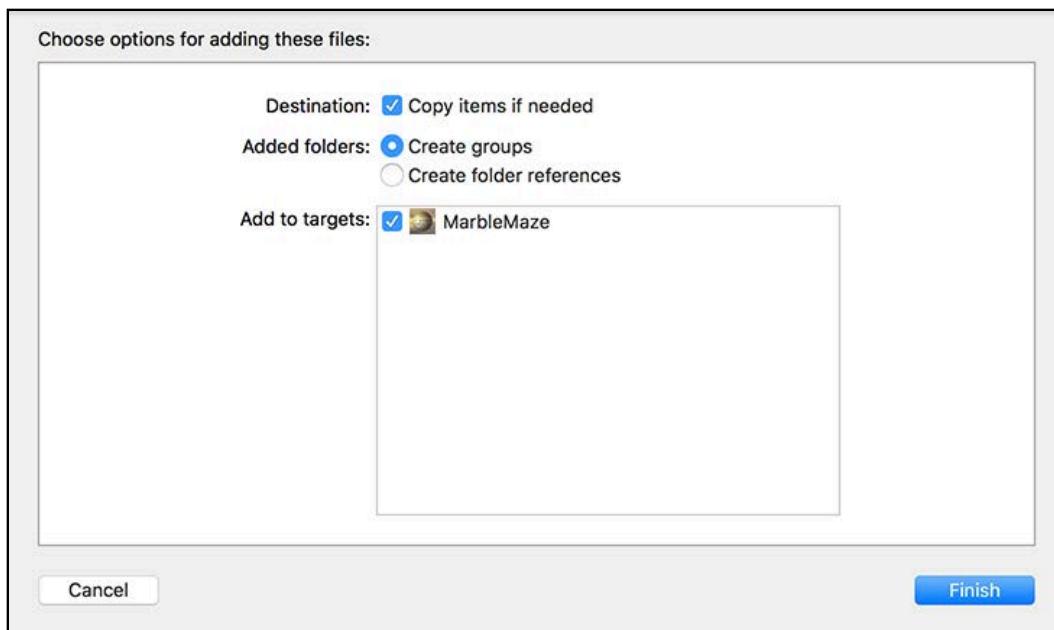
```
var game = GameHelper.sharedInstance  
var motion = CoreMotionHelper()  
var motionForce = SCNVector3(x:0 , y:0, z:0)
```

Here's what these helpers do in detail:

- **game**: A reference to the shared instance of the GameHelper class. It provides some simple game state management and a HUD for your game, along with some convenience functions to load and play sound effects.
- **motion**: This creates an instance of the CoreMotionHelper class. It gives you a simple way to poll the Core Motion engine for motion data at set intervals.
- **motionForce**: This property will contain a motion vector; you'll use this later as a force vector to put the ball into motion.

Sound effects

There's a set of awesome sound effects under the **resources** folder that will bring the game to life. Drag and drop the **Sounds** folder into your project from the **resources** folder:



Select **Finish** to complete the import.

Next add the following lines to `setupSounds()`:

```
game.loadSound(name: "GameOver", fileName: "GameOver.wav")
game.loadSound(name: "Powerup", fileName: "Powerup.wav")
game.loadSound(name: "Reset", fileName: "Reset.wav")
game.loadSound(name: "Bump", fileName: "Bump.wav")
```

This code is fairly straightforward; it loads the sound files into memory. You'll trigger these sound effects later in this chapter.

Node binding

In this section, you’re going to make the camera and lights follow the ball wherever it rolls; this is a common technique in 3rd-person games where the camera trails behind the hero as she runs around the level.

But first, you’ll need to attach local properties to the nodes in your game scene.

Binding to the camera node

Your first task is to make the camera focus continuously on the ball. The camera position won’t change, but the camera rotation instead will adjust to follow the ball. To demonstrate this to yourself, hold your head still and roll your eyes around looking at random objects in the room. Are you rolling your eyes at me?! :]

Add the following property to the top of GameViewController class:

```
var cameraNode: SCNNode!
```

This will hold your cameraNode once you’ve attached to it in the game scene.

Next, add the following lines to the bottom of setupNodes() after the point where you’ve attached to the ballNode:

```
// 1  
cameraNode = scnScene.rootNode.childNode(withName: "camera",  
    recursively: true)!  
// 2  
let constraint = SCNLookAtConstraint(target: ballNode)  
cameraNode.constraints = [constraint]
```

Here’s what’s going on above:

1. Here, you attach **cameraNode** to the actual **camera** in the game scene.
2. This sets up a SCNLookAtConstraint to look at the ballNode and adds the constraint to the actual camera’s constraints.

Gimbal locking

When the camera has SCNLookAtConstraint applied, SceneKit will do whatever it takes to rotate the camera towards the ball as it rolls around. This “whatever it takes” approach can produce unwanted rotations where the camera might tilt to the left or right.

This wouldn’t be a problem if you were controlling a light, but because you’re controlling a camera this behavior could cause some odd viewing angles for the player. Instead, you want the camera to stay horizontal at all times.

SceneKit has you covered, saving you from hours of research and a serious math-related headache. :] Enabling the `isGimbalLockEnabled` property on the actual constraint tells SceneKit to keep the camera aligned horizontally as it follows its target.

Add the following line to the bottom of `setupNodes()`:

```
constraint.isGimbalLockEnabled = true
```

This will enable gimbal lock for your camera constraint — and prevent your viewer from getting motion sick. :]

Binding to the follow nodes

Add the following property to the `GameViewController` class:

```
var cameraFollowNode:SCNNode!
var lightFollowNode:SCNNode!
```

This will hold the `cameraFollowNode` and `lightFollowNode` once attached.

Next, add the following to the bottom of `setupNodes()`:

```
// 1
cameraFollowNode = scnScene.rootNode.childNode(
    withName: "follow_camera", recursively: true)!
// 2
cameraNode.addChildNode(game.hudNode)
// 3
lightFollowNode = scnScene.rootNode.childNode(
    withName: "follow_light", recursively: true)!
```

Taking a closer look at the code segment:

1. This attaches `followCameraNode` to the **follow_camera** node in the game scene.
2. This adds the HUD to the camera as a child node so that it remains in view of the camera no matter what direction it faces.
3. This attaches `followLightNode` to the **follow_light** node in the game scene.

Game state management

Now that you've attached to all the important nodes in the game scene, you need to sort out three basic game states:

- **waitForTap:** This is the moment in-between games when the player has not yet started controlling the ball. In this state, you'll let the camera spin around the ball and display a message indicating the game is waiting for input.

- **playing:** This state triggers when the user taps the screen to start the game. The player can control the ball in this state.
- **gameOver:** This state triggers when the player fails to collect another pearl of life in time or drops into the abyss. This state will automatically move to the **waitForTap** state after a few seconds.

Next, you'll add a few useful functions to help manage these states. Add the following to the GameViewController class:

```
// 1
func playGame() {
    game.state = GameStateType.playing
    cameraFollowNode.eulerAngles.y = 0
    cameraFollowNode.position = SCNVector3Zero
}
// 2
func resetGame() {
    game.state = GameStateType.tapToPlay
    game.playSound(node: ballNode, name: "Reset")
    ballNode.physicsBody!.velocity = SCNVector3Zero
    ballNode.position = SCNVector3(x:0, y:10, z:0)
    cameraFollowNode.position = ballNode.position
    lightFollowNode.position = ballNode.position
    scnView.isPlaying = true
    game.reset()
}
// 3
func testForGameOver() {
    if ballNode.presentation.position.y < -5 {
        game.state = GameStateType.gameOver
        game.playSound(node: ballNode, name: "GameOver")
        ballNode.run(SCNAction.waitForDurationThenRunBlock(
            duration: 5) { (node:SCNNode!) -> Void in
                self.resetGame()
            })
    }
}
```

Here's the purpose of each function:

1. **playGame():** A call to this function switches the game into the `.playing` state, which starts the game. It also performs some basic cleanup and resets the **cameraFollow** node's angle and position.
2. **resetGame():** A call to this function puts the game into the `.waitForTap` state. It also plays a "Reset" sound effect, then does some basic cleanup by resetting the ball's position and velocity. It also resets the `cameraFollowNode` and `lightFollowNode` positions. Note that the `ballNode` position is set to a high `y`-value; this creates the effect of the ball dropping out of thin air into the sky maze.

3. **testForGameOver()**: A call to this function checks if the ball's y-position has dropped lower than -5 units. If so, the ball has fallen off the edge into the abyss. Whoops! :] It then switches to the `.gameOver` state and plays the "GameOver" sound effect. After five seconds, it automatically triggers a call to `resetGame()`, placing the game back into the `.waitForTap` state.

Note: During the `.waitForTap` state, there are no active animations or physics updates, so the renderer stops updating every frame. Later on in this chapter, you will be spinning the camera around the ball during this game state; therefore, the renderer will continue to update every frame. This is why `resetGame()` sets the view's `playing` property to `true`: this forces the renderer to update every frame.

With the basic game state functions in place, you need to set the game's initial state by calling `resetGame()`. Add the following function call to the bottom of `viewDidLoad()`:

```
resetGame()
```

Once everything has been set up, this will set the game into the initial state `.waitForTap`.

To start the game, the player simply has to tap on the display. Add the following lines of code to the `GameViewController` class:

```
override func touchesBegan(_ touches: Set<UITouch>, with event: UIEvent?) {
    if game.state == GameStateType.tapToPlay {
        playGame()
    }
}
```

This adds a `touchesBegan(_: event:)` event handler to the `GameViewController` class; if the game is in the `.tapToPlay` state, this will start the game by calling `playGame()`.

Motion control

Now that you've attached to all the important nodes and have the game states ready, you can set the ball rolling, so to speak! Can you hear the crowd chanting? "Move That Ball! Move That Ball!" :]

First, add the following to the `GameViewController` class:

```
func updateMotionControl() {
    // 1
    if game.state == GameStateType.playing {
```

```
    motion.getAccelerometerData(interval: 0.1) { (x,y,z) in
        self.motionForce = SCNVector3(x: Float(x) * 0.05, y:0,
                                      z: Float(y+0.8) * -0.05)
    }
    // 2
    ballNode.physicsBody!.velocity += motionForce
}
```

Taking a closer look:

1. First, the function updates the `motionForce` vector with the current motion data.
2. Then it adds the `motionForce` vector to the ball's velocity.

There's one thing left to do: call `updateMotionControl()` from the `SCNSceneRenderDelegate`. Add the following call to `renderer(_, updateAtTime)`:

```
updateMotionControl()
```

This will perform a motion update call 60 times a second, although the actual motion sensor is polled at a much lower pace to preserve energy.

Note: To play, hold the device in a comfortable position, tilted backwards at a 45° angle, just as you would normally look at your phone.

Build and run the game on your device:



The ball spawns out of mid-air and drops down onto the sky maze. This is `resetGame()` at work. You'll also hear a loud thundering sound — hopefully you didn't drop your phone when it went off! :]

Touching the display starts the game. Lo and behold, you can control the ball simply by tilting the device left, right, forward and back. Smooth! :]



Try to collect a pearl — careful, don't fall!

Health indicators

Recall that the glowing effect you added to the ball was to serve as a health indicator; the ball's health will diminish over time until the emission intensity runs out at `0.0`. If the player collects pearls of life along the way, the health — and emission intensity — will be restored to `1.0`.

You'll need a function to replenish the health bar. To do that, add the following to the `GameViewController` class:

```
func replenishLife() {
    // 1
    let material = ballNode.geometry!.firstMaterial!
    // 2
    SCNTransaction.begin()
    SCNTransaction.animationDuration = 1.0
    // 3
    material.emission.intensity = 1.0
    // 4
```

```
SCNTransaction.commit()  
// 5  
game.score += 1  
game.playSound(node: ballNode, name: "Powerup")  
}
```

Taking a closer look at exactly what the above code does:

1. To access the emission map, you need to get the first and only material for the ballNode.
2. This starts a SceneKit animation transaction sequence by specifying **SCNTransaction.begin()**. At this point, you can set target values for all the animatable SceneKit properties you want to animate; in this case, the emission intensity. `animationDuration = 1.0` sets the duration of the animation sequence to one second.
3. Here you set the material's emission intensity to `1.0`. This doesn't set the actual value, but sets the value you *want* it to be once the animation completes.
4. This commits the animation transaction. Once committed, SceneKit will start animating the emission value from its current value to the requested value of `1.0`.
5. The rest of the code increases the score and plays a nice "Powerup" sound effect.

The first spot where you'll need to replenish the health is when you enter the `.playing` state. Add the following line to the end of `playGame()`:

```
replenishLife()
```

Build and run your project; you'll hear a cool sound effect and should notice the indicator on the ball starts nice and bright:



Diminishing life

You have a function that will replenish life, but what about the reverse? Health diminishes over time, so you'll need a function to call for every frame update.

Add the following to the GameViewController class:

```
func diminishLife() {  
    // 1  
    let material = ballNode.geometry!.firstMaterial!  
    // 2  
    if material.emission.intensity > 0 {  
        material.emission.intensity -= 0.001  
    } else {  
        resetGame()  
    }  
}
```

Taking each numbered comment in turn:

1. Again, you're accessing the emission map of the ball's first and only material.
2. If the emission intensity is still above 0, slowly decrease its value by 0.001 units. Once the emission intensity drops below 0, life has run out for the ball so you trigger the `resetGame()` function.

You'll add a call to `diminishLife()` later in this chapter when you look at checking for the `.gameOver` state.

Other than that, there's still a few obvious problems that needs to be addressed:

- The camera is simply tracking the ball, not following it as you intended.

- The light isn't following the ball.
- There's no HUD, leaving the player wondering what the heck is going on.
- If the ball drops into the abyss, the game gets stuck and you have to restart it in order to play again.

You're so close — time to fix these issues and give your game that final polish!

Camera and lights

`cameraFollowNode` is a special node that acts as a selfie stick for the camera node. But just like a real selfie stick, something needs to "hold" the other end of the stick.

You can't just make the **cameraFollow** node a child node of the ball, because the camera would spin like crazy as the ball rolls around! (Talk about game-induced motion sickness!) Instead, you created the **followCamera** node in the **rootNode**, so you can simply place it at the same position as the ball. Therefore, you need to update the `cameraFollow` position to match that of the ball as it rolls around.

Add the following function to the `GameViewController` class:

```
func updateCameraAndLights() {  
    // 1  
    let lerpX = (ballNode.presentation.position.x -  
        cameraFollowNode.position.x) * 0.01  
    let lerpY = (ballNode.presentation.position.y -  
        cameraFollowNode.position.y) * 0.01  
    let lerpZ = (ballNode.presentation.position.z -  
        cameraFollowNode.position.z) * 0.01  
    cameraFollowNode.position.x += lerpX  
    cameraFollowNode.position.y += lerpY  
    cameraFollowNode.position.z += lerpZ  
    // 2  
    lightFollowNode.position = cameraFollowNode.position  
    // 3  
    if game.state == GameStateType.tapToPlay {  
        cameraFollowNode.eulerAngles.y += 0.005  
    }  
}
```

Taking the above function step-by-step:

1. This is a cool set of calculations; instead of simply setting the `cameraFollowNode` position to that of `ballNode`, you calculate a linearly-interpolated position to slowly move the camera in the direction of ball. This creates a spectacular lazy camera effect.
2. This sets **lightFollowNode** to the same position as the camera so that whatever is in front of the camera is well-lit.

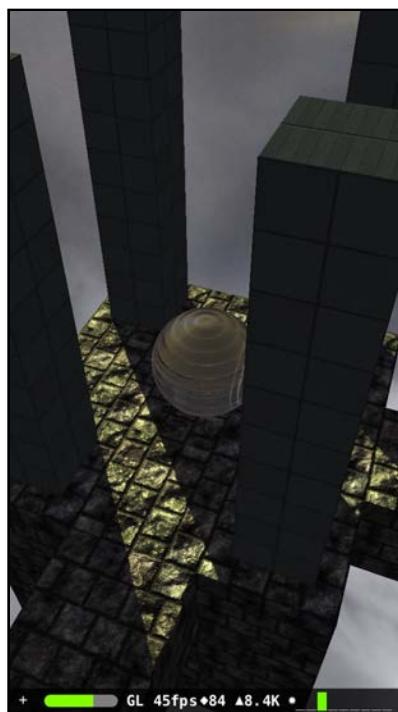
- Finally, this simply rotates the camera on its y-axis if the game is in a `.tapToPlay` state. This shows off the cool 3D graphics during the short intermission between games.

To call this function, add the following to the bottom of `renderer(_:, updateAtTime:)`:

```
updateCameraAndLights()
```

This ensures that you update the camera and lights with every single frame.

Build and run your game again to see the effect of your changes:



The ball drops out of the sky into the maze and the camera starts spinning around. This is what the camera will do while the game is in a `.WaitForTap` state. Cool! :]

Tap on the display to start the game:



Hey! Now you can control the ball properly, and the camera and light follows it as it rolls around the maze. Wow — was that even easier than you thought?

HUD updates

Time to give the player something to tell them what the heck is going on! The heads-up display is sufficient for this.

Add the following function to GameViewController class:

```
func updateHUD() {
    switch game.state {
        case .playing:
            game.updateHUD()
        case .gameOver:
            game.updateHUD(s: "-GAME OVER-")
        case .tapToPlay:
            game.updateHUD(s: "-TAP TO PLAY-")
    }
}
```

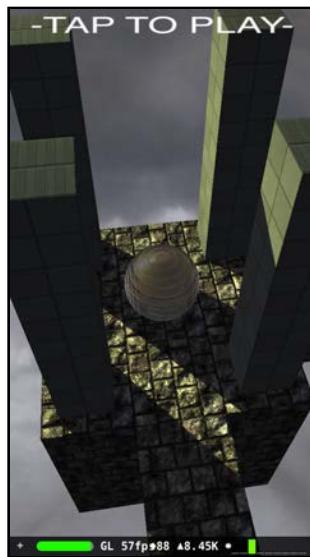
The HUD updates according to the current game state. When the game is in the `.playing` state, the HUD will display the current score. When in the `.gameOver` state, it will display "-GAME OVER-". Finally, when the game is in the `.tapToPlay` state you'll show "-TAP TO PLAY-".

To make sure you update the HUD accordingly, add the following call to the bottom of `renderer(_:, updateAtTime:)`:

```
updateHUD()
```

This ensures that the HUD updates with every frame.

Build and run your game; you'll notice the HUD appears and gives the player a little more information than before:



Finishing touches

Marble Maze is so close to being done; you just need to add a few final touches.

Testing for game-over

At the moment, the ball is immortal — unless it takes a nose-dive into the abyss, at which point the game gets stuck as the camera continues to track the ball's descent.

To fix that, add the following code to the bottom of `renderer(_ , updateAtTime)`:

```
if game.state == GameStateType.playing {  
    testForGameOver()  
    diminishLife()  
}
```

The game will only test for the game over condition while in the `.playing` state; you also make a call to `diminishLife()` make the ball's health deteriorate.

Build and run your game; you should be able to transition the game through all available game states without issue. The ball is no longer immortal, and should die after a few seconds. Hm. That's not much fun.

Looks like it's time to add a mechanism to replenish your health!

Replenishing life

At the moment, collecting a pearl of life makes the pearl disappear, but your score doesn't increase, nor does the ball's health. To fix that, simply add a call to `replenishLife()` in `physicsWorld(_ didBeginContact)`, inside the block that handles contact with pearls:

```
replenishLife()
```

Build and run your game; when you collect a pearl, the ball's health is replenished and your score increases by one. Excellent! :]

Adding sound effects

When the ball bumps against the pillars and crates, it would nice to give the player some sort of "bump" noise.

To do that, add the following bit of code to `physicsWorld(_ didBeginContact)`, inside the block that handles contact with pillars and crates:

```
game.playSound(node: ballNode, name: "Bump")
```

Build and run your game; bonk that ball into a pillar or crate and you'll hear something go bump in the night! :]

Removing debug information

You can now remove the debug information, since you're done building your game. Find the following two lines of code inside `setupScene()` and comment them out like so:

```
//scnView.allowsCameraControl = true  
//scnView.showsStatistics = true
```

This will remove the bottom debug information bar from your game and will also remove the ability to rotate the camera freely.

Congratulations! You've completed Marble Maze; build and run and enjoy the fruits of your labor. Just don't get too close to the edge! :]

Where to go from here?

A very famous astronaut once said: "One small step for man, one giant leap for mankind!". Well you just took a massive leap into a bright future of 3D game development with SceneKit. Well done! :]

Here's a recap of what you covered in this chapter:

- **3D Motion Control:** You learned how to add basic motion control to your game by using the motion data as a force vector added to the ball's velocity.
- **Gimbal locking:** You had a quick introduction to gimbal locking and how to overcome the issue of camera rotation by enabling a simple property.
- **Animating properties:** You now know how to use SCNTransaction to animate properties.
- **Lerp Camera:** You learned how to do a basic linear interpolation calculation to create a lazy camera effect, which adds a professional feel to the game.

Here are some other ideas you can add to make the game even better:

- **More game elements:** Think about adding bad guys that patrol certain sections of the maze. Maybe add some icy blocks that reduce friction and make the ball slip and slide?
- **More sets and levels:** You can let your imagination go wild here and create some weird and twisted sets, making the game more challenging for the player as they complete each level.
- **More juice:** More sound effects! Camera shaking! Particle effects! What else can you think to add to make the game exciting (and slightly unpredictable) for your player?

OK, now go and play with your game some more — you know you want to! :]

Note: As always, you can find the final project under the **projects/final/MarbleMaze/** folder.

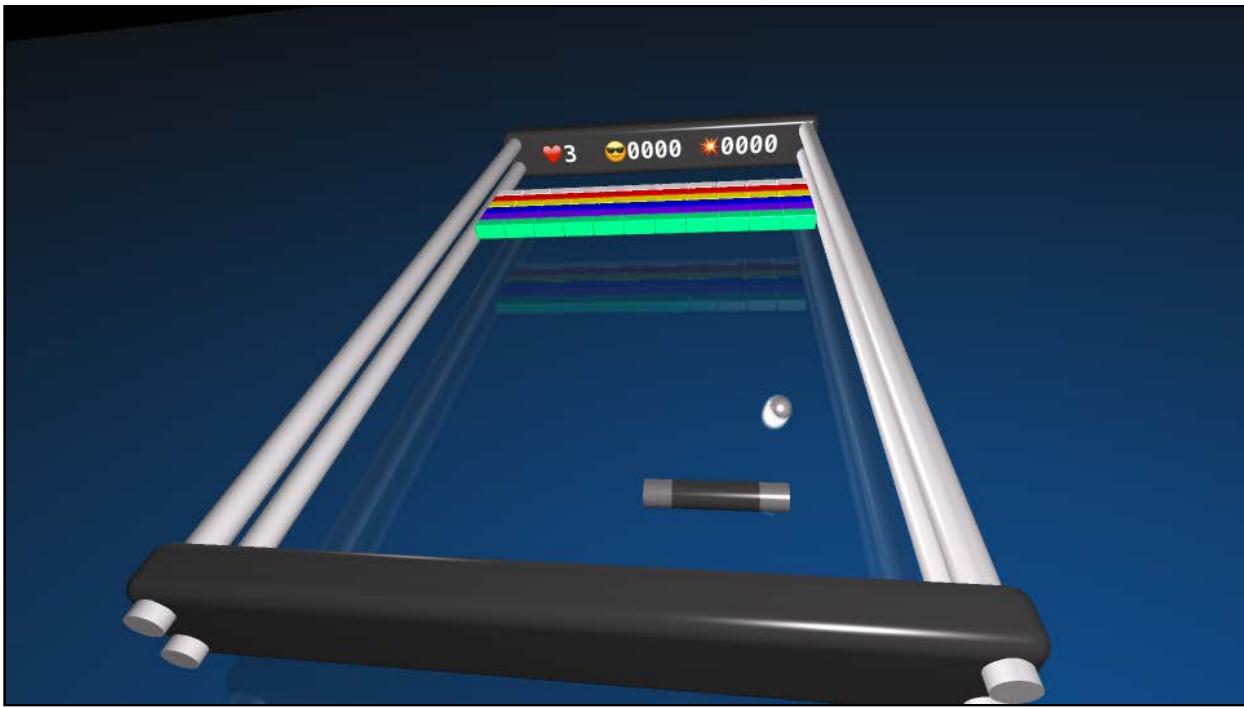
Section IV: Cross Platform Games

In this section, you'll learn a few cool tricks on how to make your games run on other platforms including *macOS*, *tvOS* and even *watchOS*.

You'll start by creating a *macOS* version of *Geometry Fighter*.



Then, you'll create a *tvOS* version of *Breaker*.



Finally, you'll create a *watchOS* version of *Geometry Fighter*.



[Chapter 16: macOS Games](#)

[Chapter 17: tvOS Games](#)

[Chapter 18: watchOS Games](#)

Chapter 16: macOS Games

Chris Langridge

Now that you've created a few SceneKit games for iOS, you're ready to target entirely different platforms — like macOS.

Why bother with macOS? Isn't iOS good enough?

Porting to macOS can prove to be a great strategic move for your game by promoting it to an entirely different audience, which also gives you another revenue stream for your game with comparatively little effort.

In this chapter, you'll learn how to take an existing iOS game — Geometry Fighter — and turn it into a game that works on macOS. You'll also learn about how to create a macOS game from a scratch template.

Are you ready? Great — time to get to work.

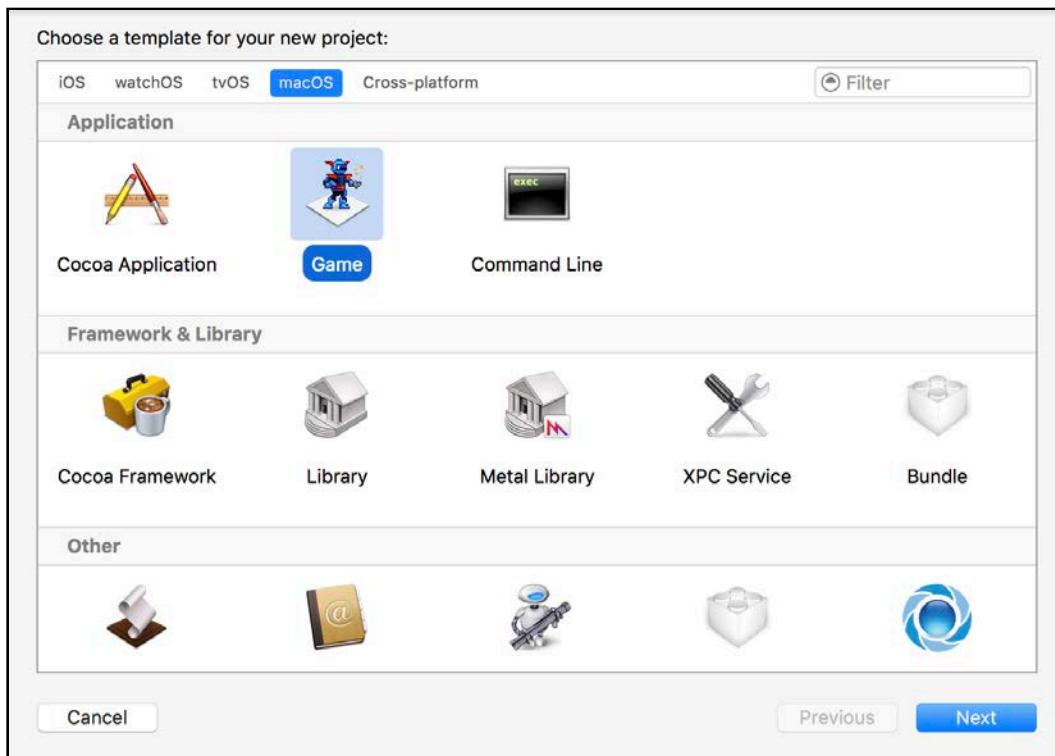
Getting started

Before you start on Geometry Fighter, you may be wondering how to create a SceneKit game project for macOS from scratch. Well, wonder no more — simply follow these steps.

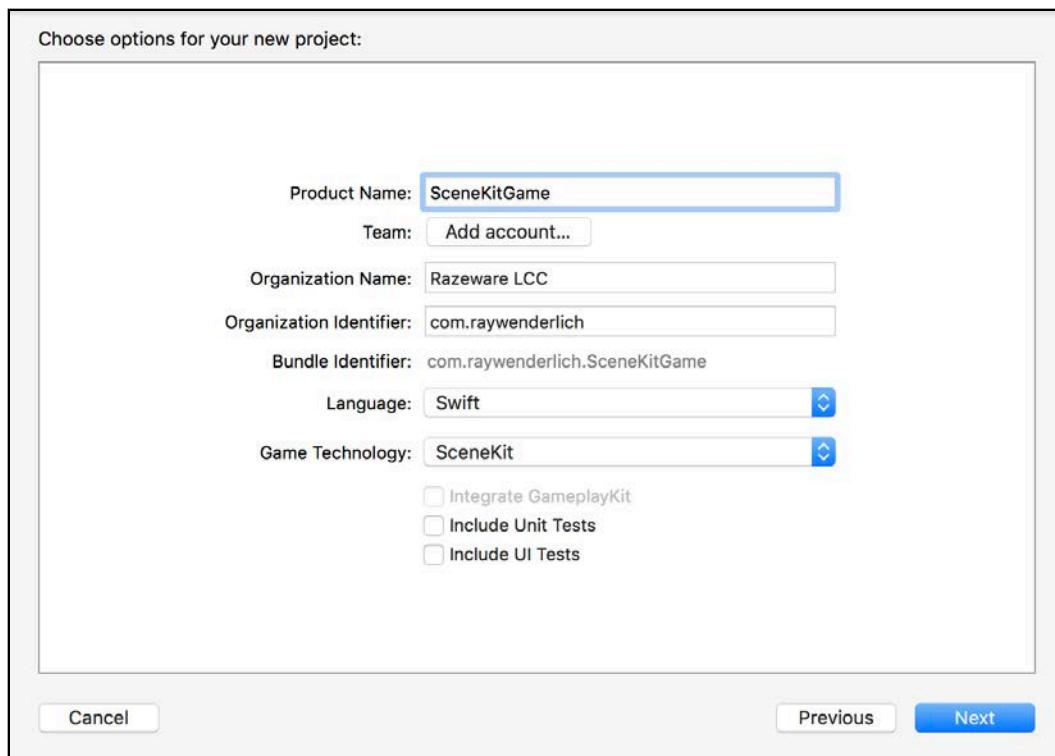
Creating the macOS game project

Open Xcode and start by creating a new project.

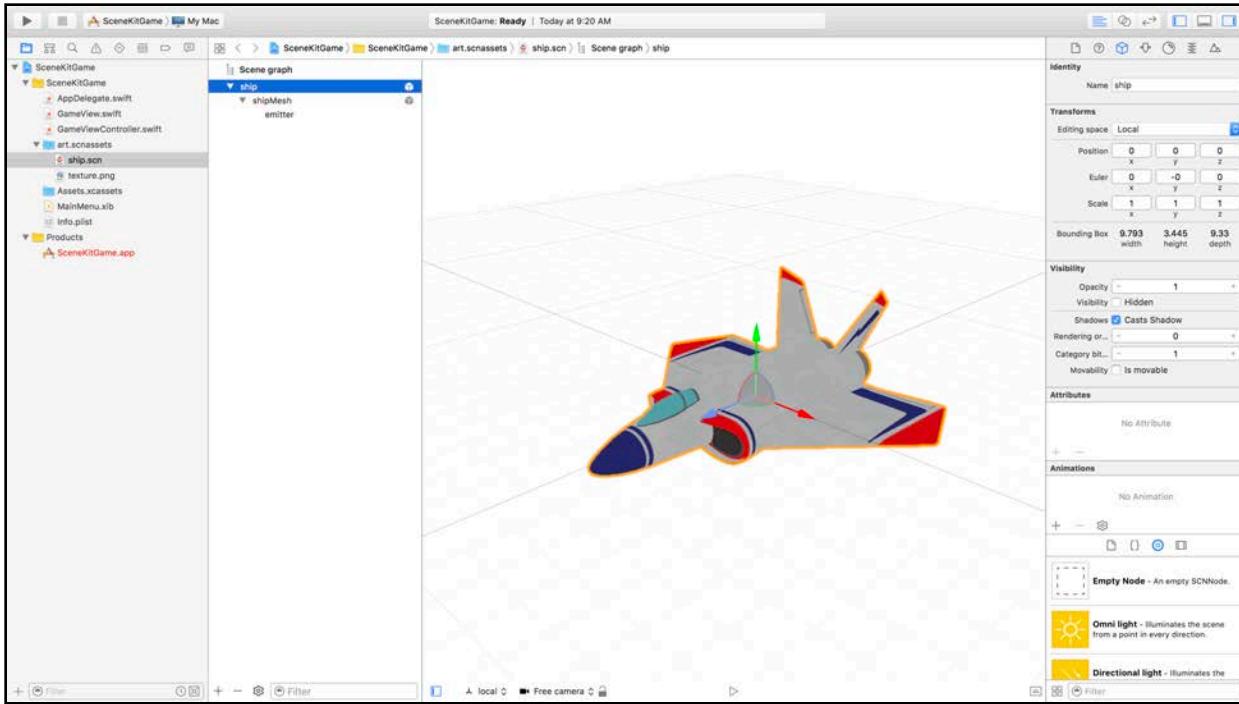
Choose **macOS** for the platform and select the **Game** project for the template. Click **Next** to continue.



For the Product Name, type **SceneKitGame**. Then, select **Swift** for the Language and **SceneKit** for the Game Technology. Don't worry about **Unit** and **UI Tests**, just click **Finish** to complete the project creation process.



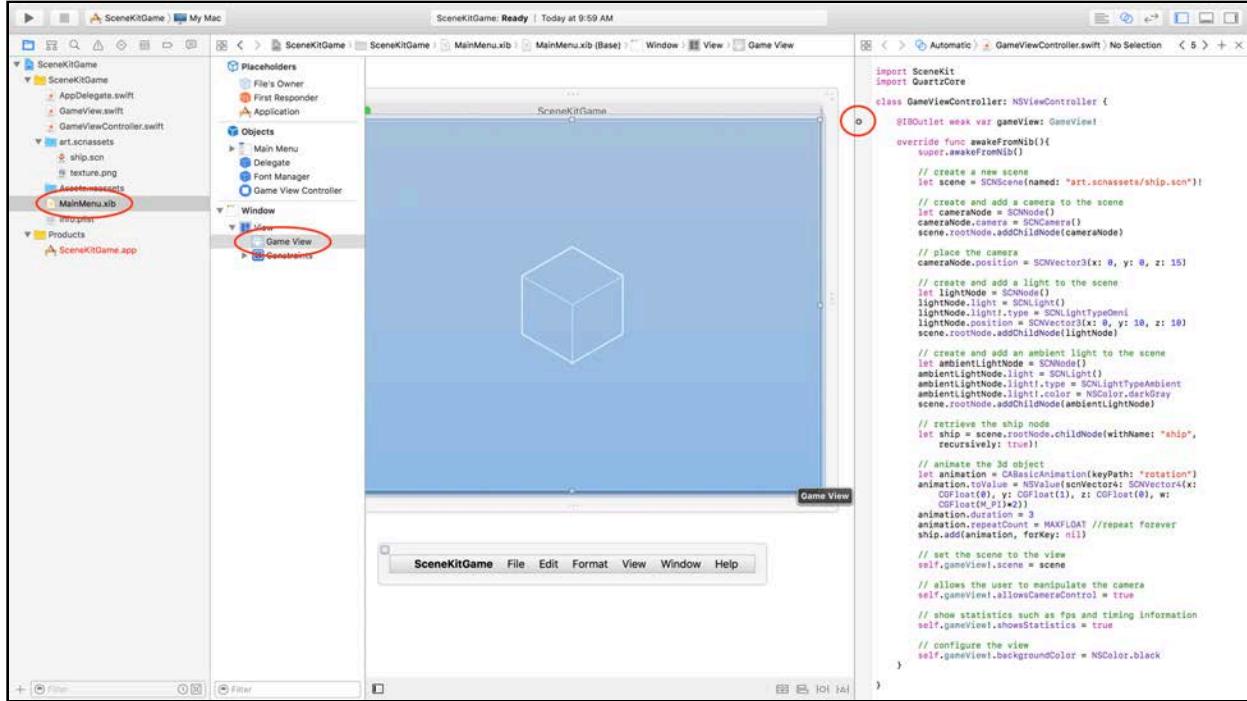
The generated project looks similar to a traditional iOS SceneKit game project, with a few differences:



Here's a brief overview of the most important files generated by Xcode:

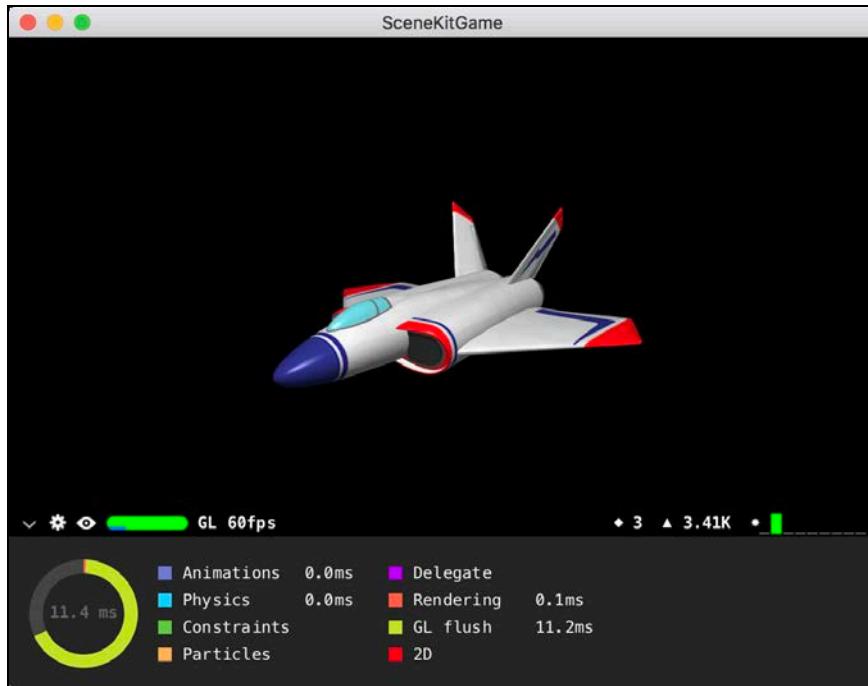
- **GameView.swift**: This is your GameView class which inherits from SCNView. Unlike iOS, macOS is not touch-centric. You typically need a keyboard and a mouse to interact with your computer. Here, you can respond to various events coming from your keyboard and mouse.
- **GameViewController.swift**: This is your GameViewController class which inherits from NSViewController, whereas an iOS game would inherit from UIViewController. It also defines the `awakeFromNib()` function which serves as the entry point for your game, similar to how `viewDidLoad()` works in iOS. Notice there's an `@IBOutlet` property defined for GameView, which is connected to the actual game view control in your **MainMenu.xib**.

To see that connection, open **MainMenu.xib** and select **Window/View/Game View**. Then, show the assistant editor and move your cursor over the `@IBOutlet` connector to see how it's connected. The **Game View** will highlight as the connected control.



Time to take your new project for a test drive. First, make sure you select **SceneKitGame > My Mac** as your **Active Scheme**.

Build and run your project; you'll see the traditional SceneKit spinning model. You can use your mouse to interact with the model, much like you would do on an iOS device.



Excellent — you just created your first macOS game! :]

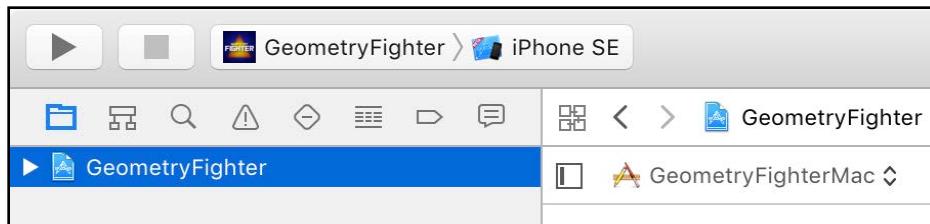
Converting SceneKit games

Now that you know the basics, it's time to move on to something more advanced. Instead of using the basic old SceneKit starter template project, you'll be using a finished game project from Geometry Fighter. In this section, you'll add support for macOS.

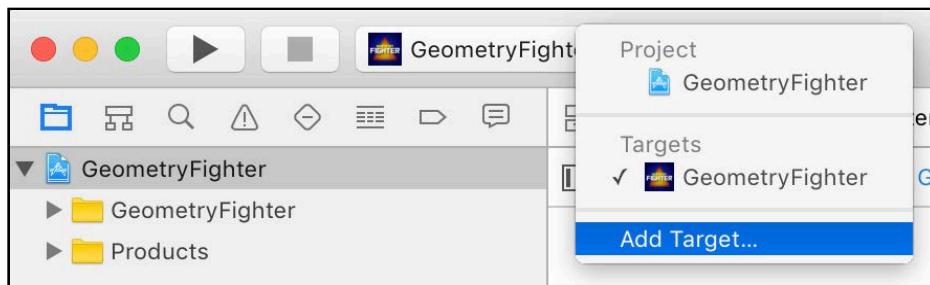
Note: You can find the starter project for this chapter under the **projects/starter/GeometryFighter/** folder. Load the project before you continue with the next section.

Adding a macOS target

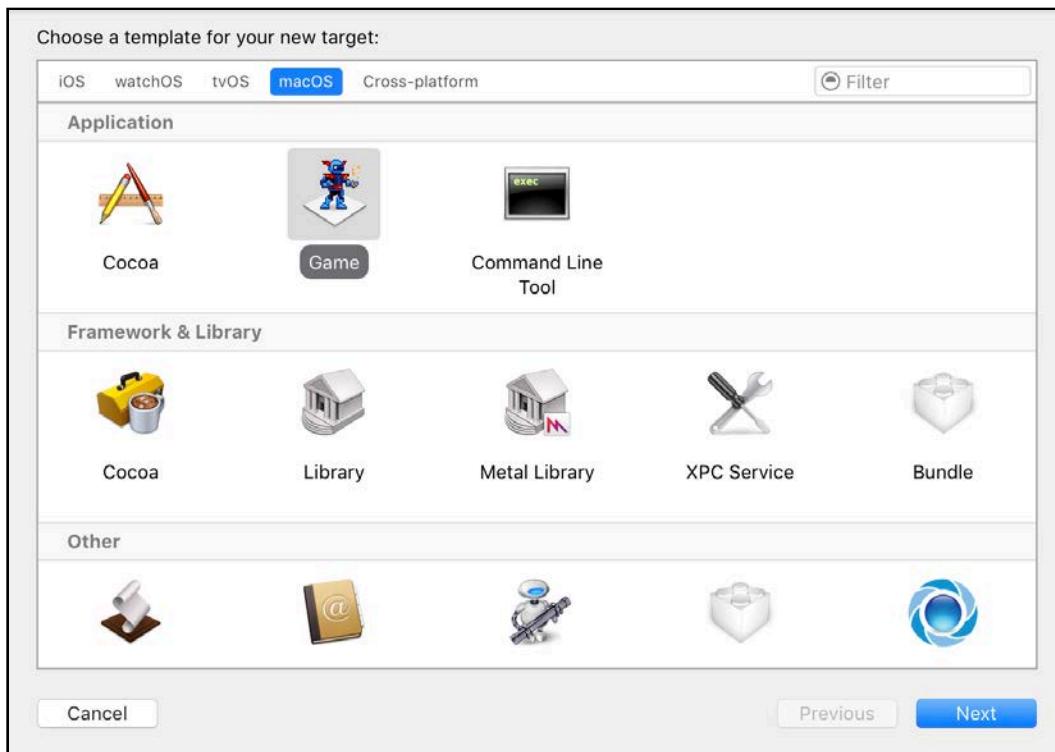
Start off by adding an additional target to your existing game project. With the project root element selected under the project navigator, click **GeometryFighter**, on the right side, and add a new target.



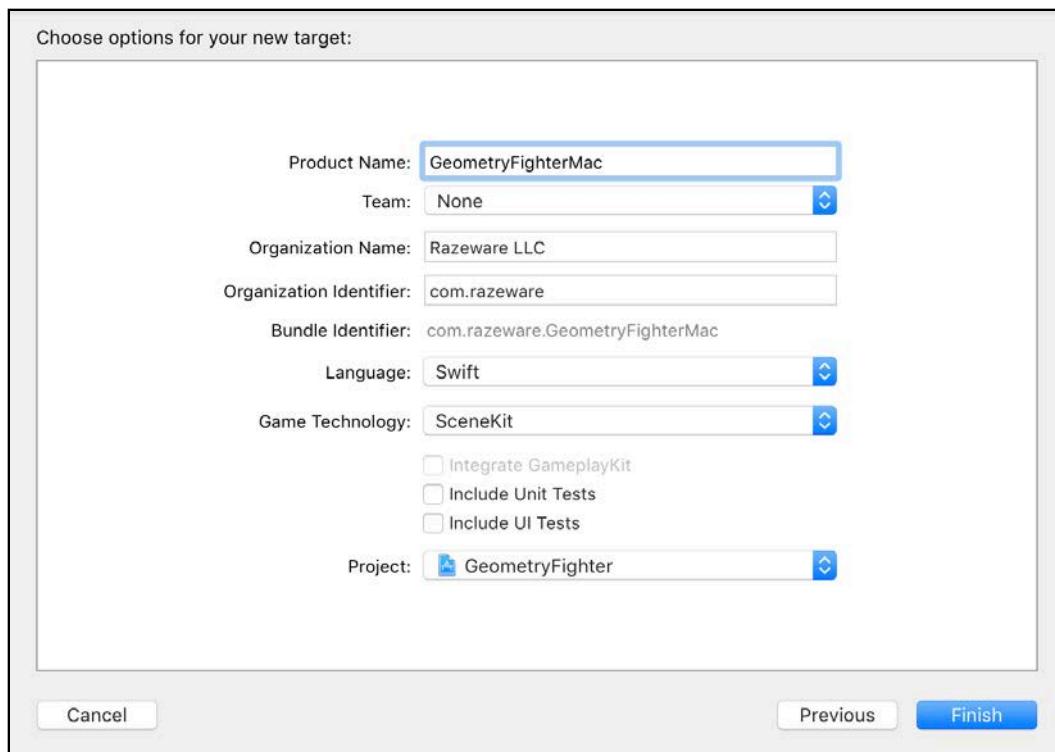
Select **Add Target...** from the popup. This allows you to choose the platform and a project template.



Choose **macOS** for the Platform. Then, select **Game** in the **Application** section for the project template.

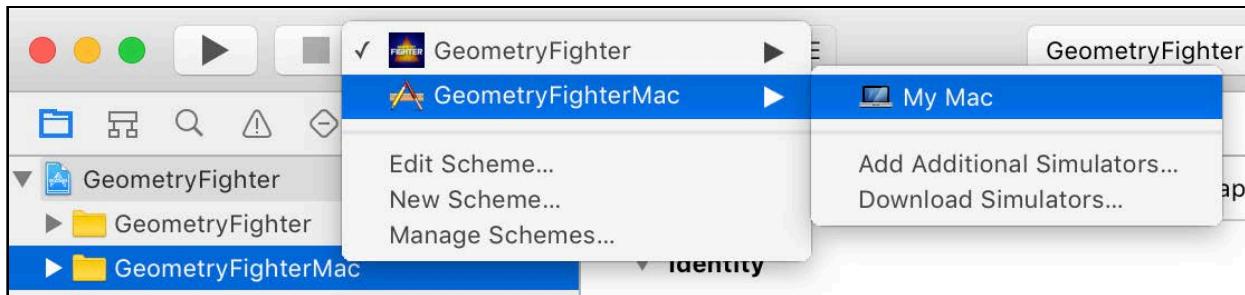


Type **GeometryFighterMac** for the Product Name. Then, select **SceneKit** for the Game Technology. Also, uncheck the options to include **Unit Tests** and **UI Tests**; for the new macOS project, you won't need those. When you're done, click **Finish** to complete the project creation.



You'll now notice a new **GeometryFighterMac** group added to the project. It contains the usual files you'll find under a typical SceneKit game template project targeted at macOS.

Select **GeometryFighterMac > My Mac** as your **Active Scheme**.



Do a quick build and run to see how the game looks:



Were you expecting to see **GeometryFighter**? Unfortunately, things aren't that easy. You only added an additional target platform to the existing iOS game project using the basic SceneKit game template. There are still a few steps you need to follow before the actual iOS game will run on macOS.

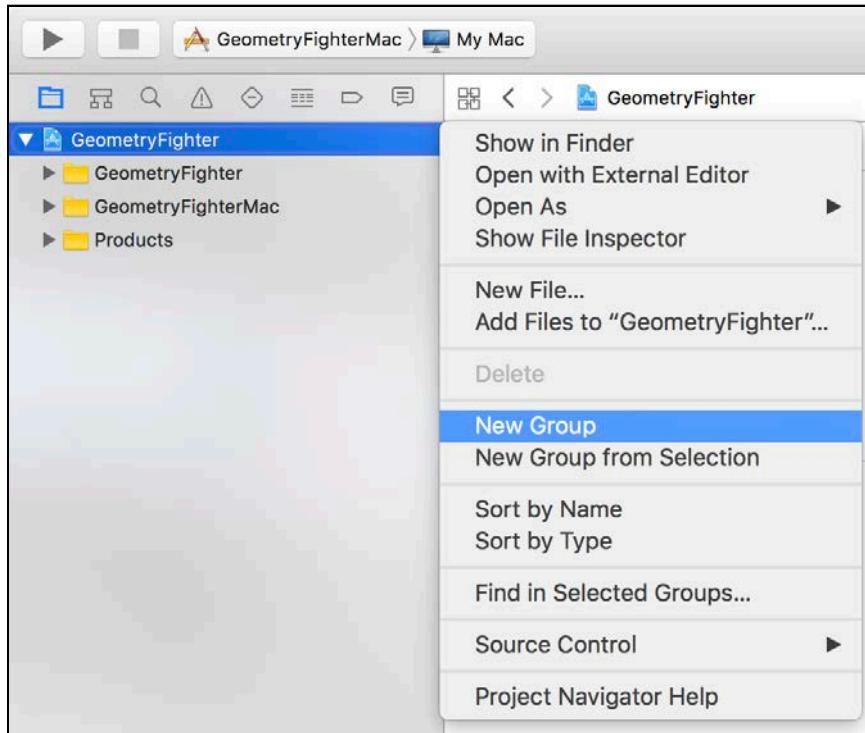
Shared content for multiple targets

The next section focuses on sharing common content between multiple platform targets. Luckily, there's already a lot of code and resources that can be shared between iOS and macOS.

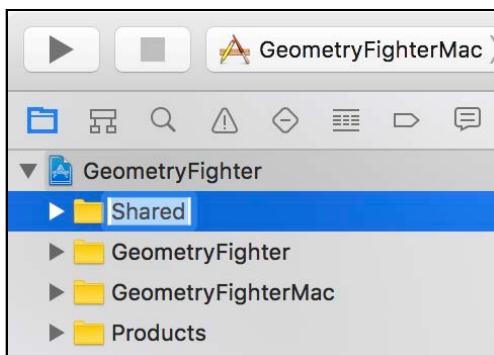
To keep things organized, you'll create a special shared group specifically for these files.

Creating a shared group

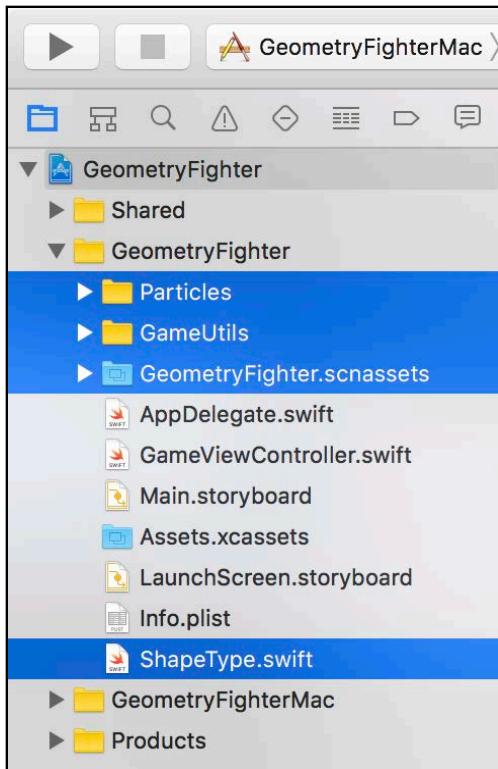
Start by creating a new **Shared** group. Right-click on the project root element **GeometryFighter** and select **New Group**. This creates a new group for your project.



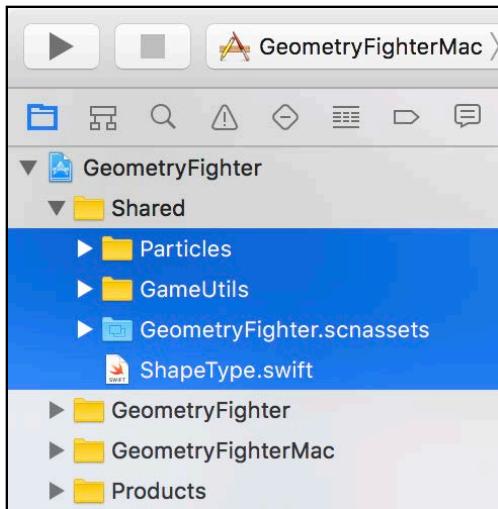
Name the new group **Shared**. Now, move the common shared files into this new group.



Expand the original iOS group **GeometryFighter** and select the following elements while holding down the Command key: **Particles**, **GameUtils**, **GeometryFighter.scnassets** and **ShapeType.swift**.



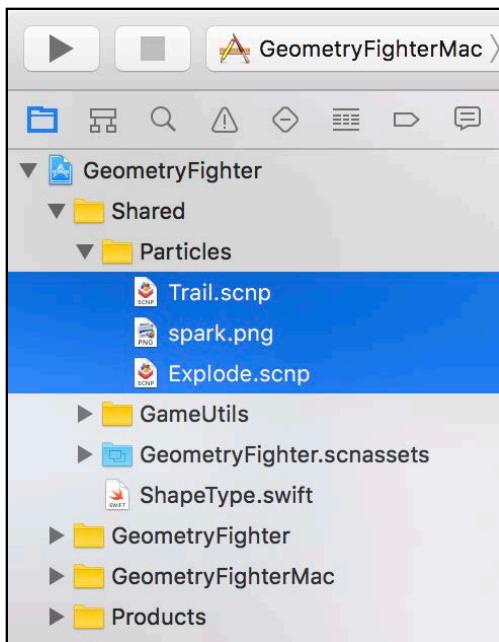
Drag and drop these files into the new **Shared** group.



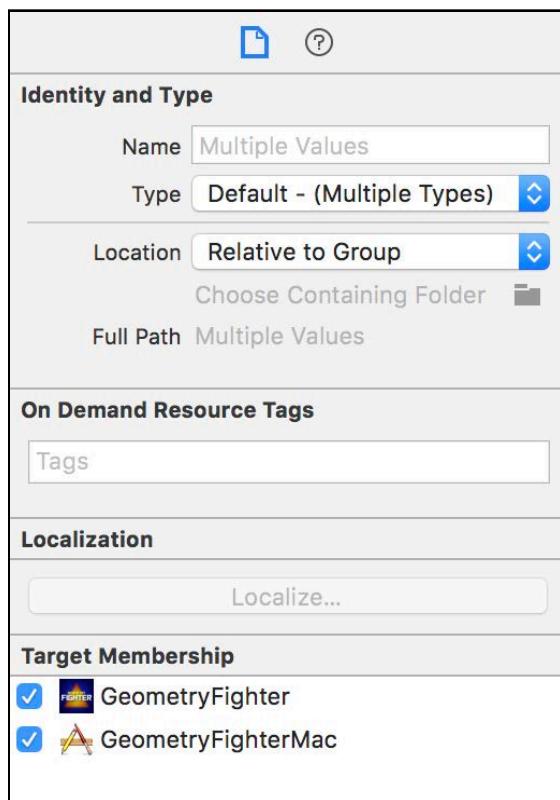
Sharing files between multiple targets

Now you need to configure the **Target Membership** for all the shared files to target both iOS and macOS.

While holding down the Shift key, select all the files under **GeometryFighter/Shared/Particles**.

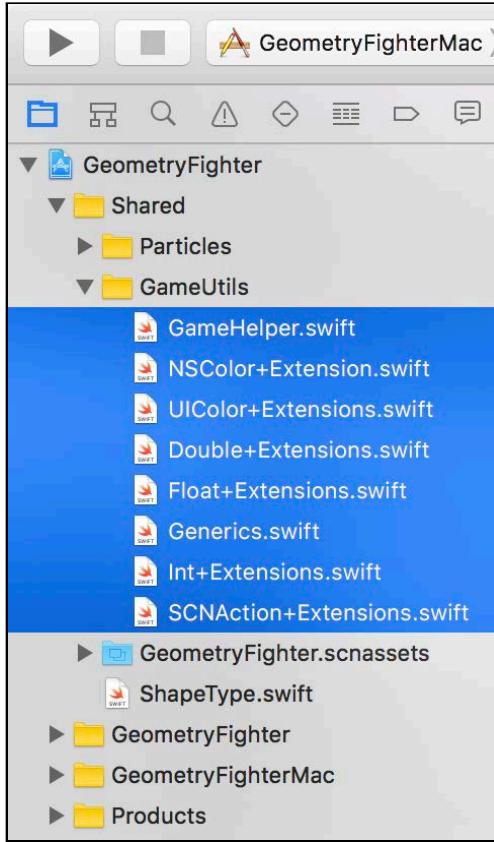


Select the File Inspector on the right, then make sure you check **GeometryFighterMac** under the Target Membership; the selected files are now shared with both the iOS target and the macOS target.

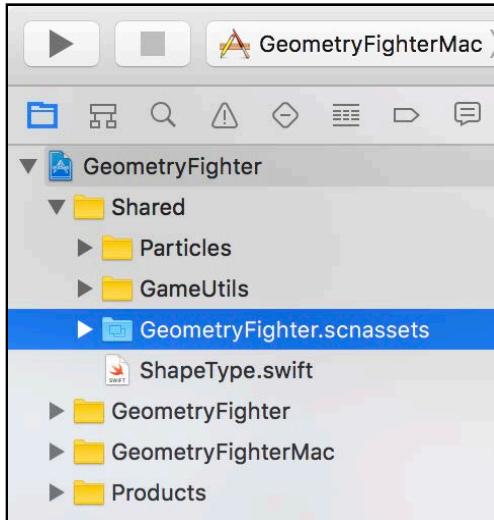


Now you need to perform the same task for all the other files under the **Shared** group.

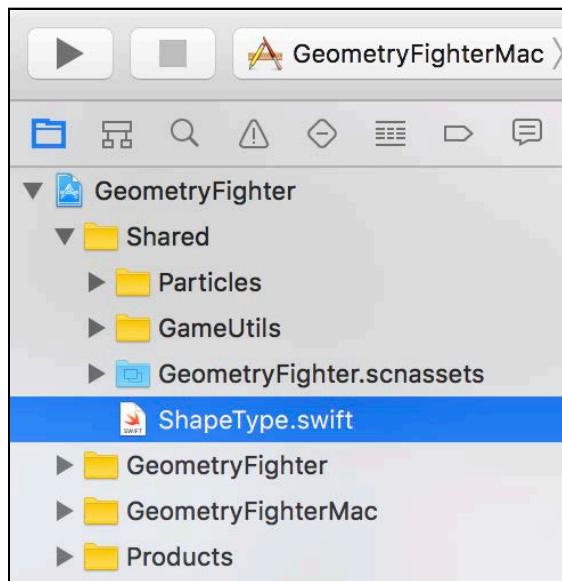
Select all the files under **GeometryFighter/Shared/GameUtils**, then select the File Inspector on the right and make sure you check **GeometryFighterMac**.



Next, select **GeometryFighter/Shared/GeometryFighter.scnassets** and select the File Inspector on the right. Make sure you check **GeometryFighterMac**.



Finally, select **GeometryFighter/Shared/ShapeType.swift**, then select the File Inspector on the right and make sure you check **GeometryFighterMac**.



Fixing the shared files

There's a slight problem — the source that's shared between iOS and macOS will not work on both platforms. The main issue is the use of `UIColor`, which is part of the `UIKit` framework and only available for iOS.

When you target iOS, you must use the `UIKit` framework for `UIColor`. However, when you target macOS, you must use the `Cocoa` framework, which include `NSColor` — the macOS counterpart of `UIColor`.

To target code for a specific platform, you can use the following:

```
#if os(iOS)
import UIKit
#endif

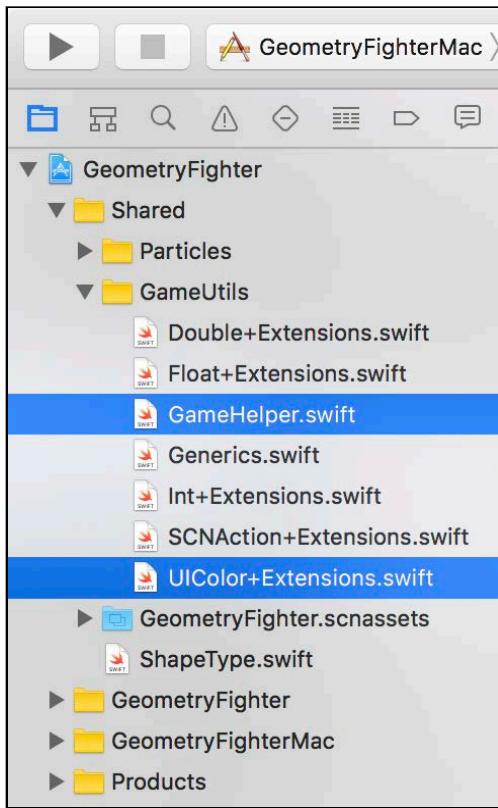
#if os(macOS)
import Cocoa
#endif
```

Now, when you target iOS, the code will import `UIKit`; when you target macOS, it'll import `Cocoa`. That's pretty darn cool! :]

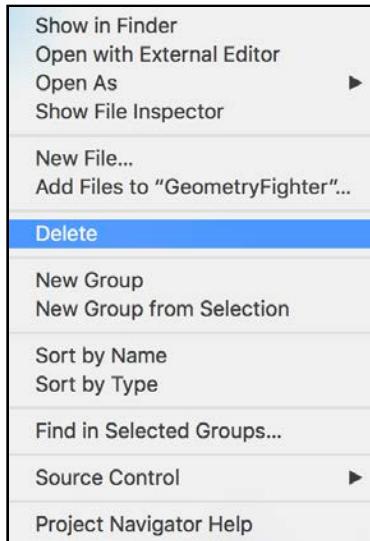
Instead of taking you through the entire process line by line, I've created a few files targeted for both iOS and macOS. You simply need to replace the current ones inside the project with these new ones.

Note: You'll find the files required for the next section under the **resources/ GameUtils/** folder.

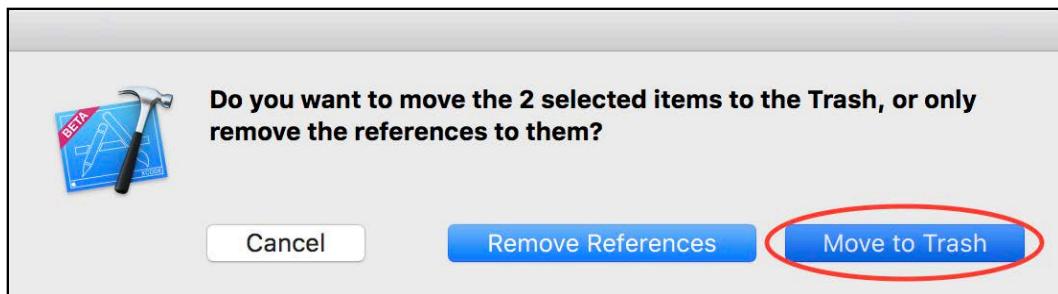
First, you need to remove the old files from the project. Select **GameHelper.swift** and **UIColor+Extensions.swift**.



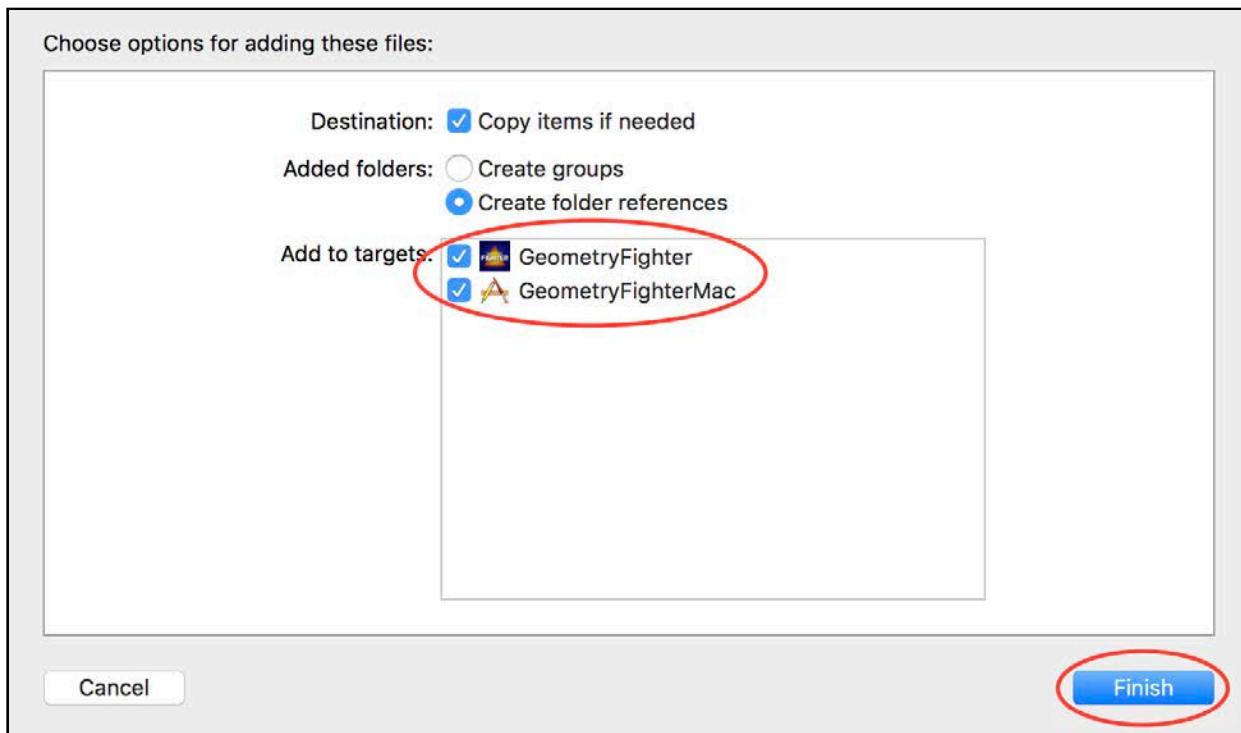
Then, right-click and select the **Delete** option.



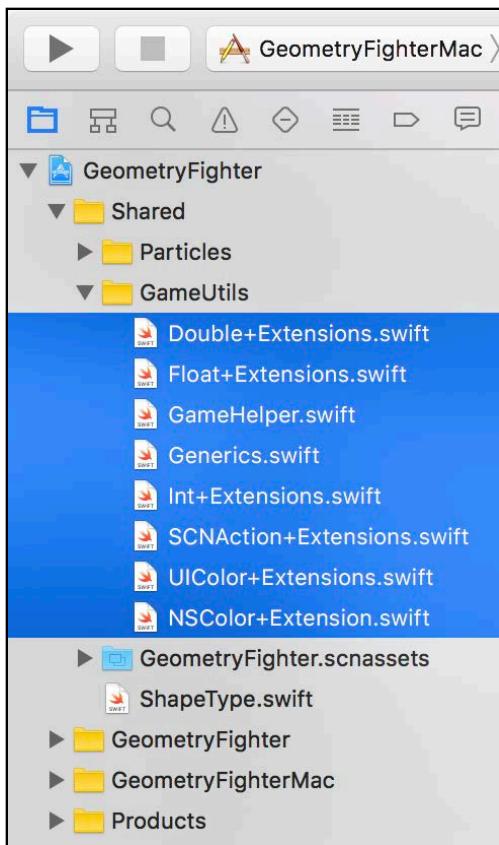
When prompted, select **Move to Trash**. That option permanently removes the files from your project.



Drag and drop all the files under **resources/GameUtils/** into your project under the **Shared/GameUtils** folder. Make sure to select all the available targets, then click **Finish** to complete the import.



Your **Shared/GameUtils** folder should now look like this:



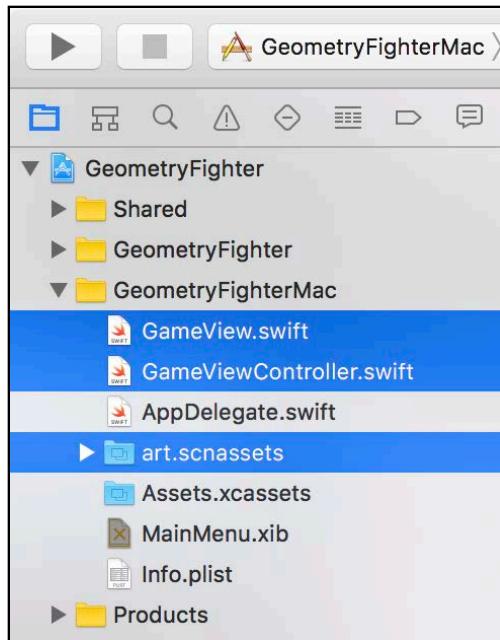
Note: Take a moment to review the files. You'll notice there's now a new **NSColor+Extensions.swift** file that targets macOS specifically. Also, notice the use of `#if os(_)` blocks placed at strategic sections in the code.

Final steps

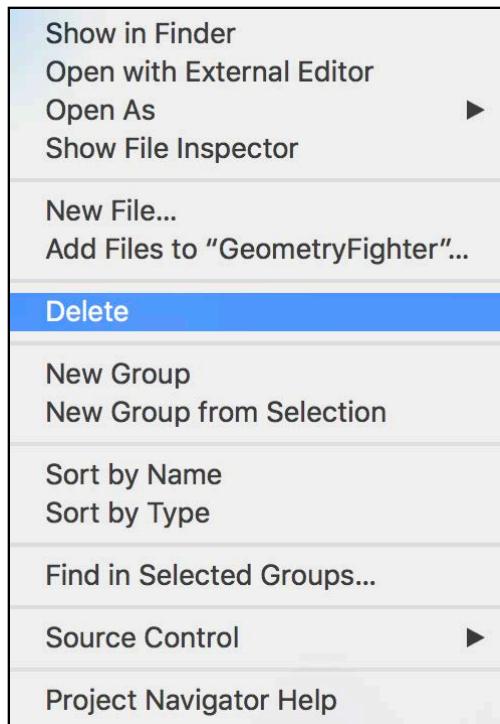
Believe it or not, you're almost done. The only thing left to do is remove all the unwanted files from the game template project and add the new game view controller.

Cleaning up the project

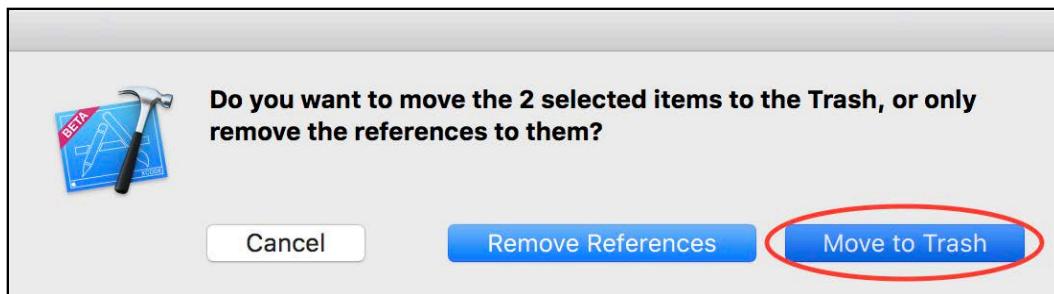
Before you can add your own game view controller, you need to remove some unwanted files. Select **GameView.swift**, **GameViewController.swift** and **art.scnassets**.



Then, right-click and select the **Delete** option.



Once again, when prompted, select **Move to Trash** to permanently remove the files from your project.

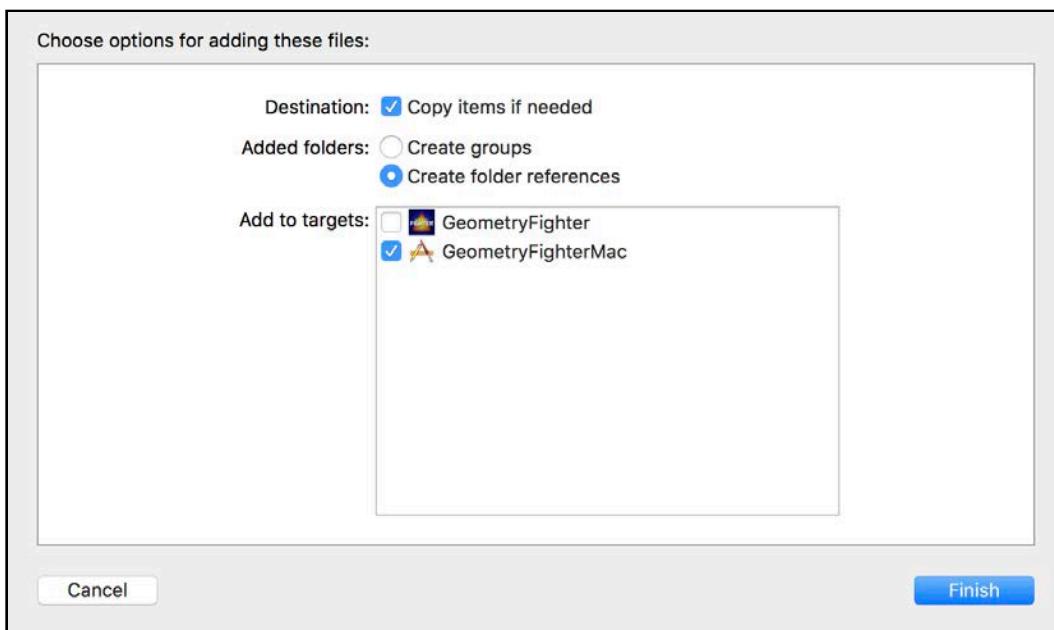


Add a new game view controller

Now you need to add the new **GameView.swift** and **GameViewController.swift** to the macOS target.

There are ready-made **GameView.swift** and **GameViewController.swift** files waiting for you under the **resources/GameViewController** folder. Drag and drop the files into your Xcode project.

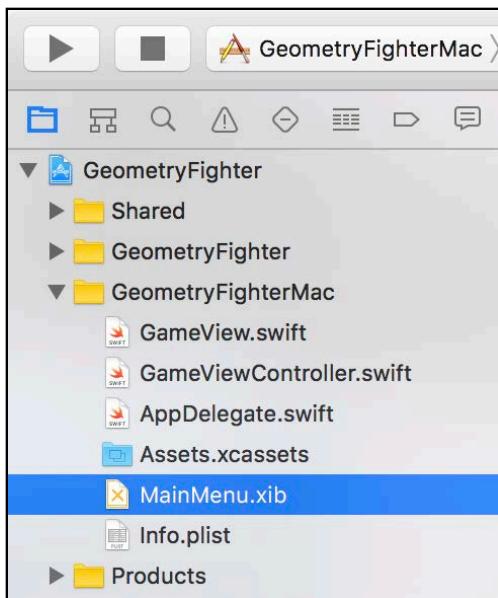
Make sure you select **Copy items if needed**. This time, only select **GeometryFighterMac** as the target. Then, click **Finish** to import the new files.



Connecting the game view

Now that you've got a new **GameViewController**, you need to connect it to the **Game View** in **MainMenu.xib**.

Select **MainMenu.xib** under the project navigator.



Enable the assistant editor and select **GameViewController.swift**.



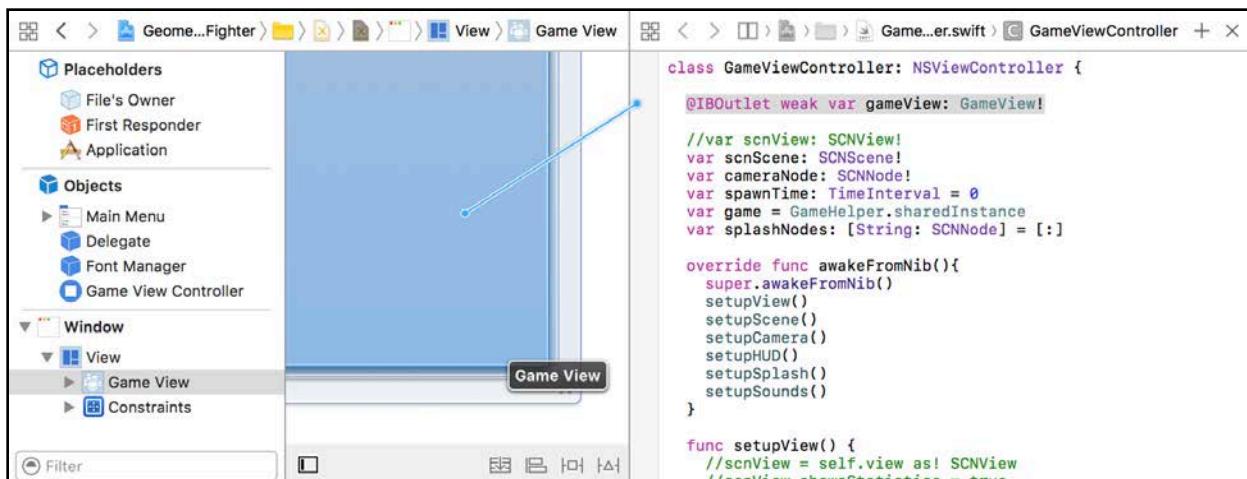
Scroll to the spot where you see the following line of code:

```
@IBOutlet weak var gameView: GameView!
```

The GameView inherits from SCNView — the same as in the iOS target, giving you access to the **Game View** control in the **MainMenu.xib** window.

You now need to connect the gameView outlet to the **Game View** inside the **MainMenu.xib** window.

Drag and drop the @IBOutlet connector into the **Game View** control.



Build and run your game, but it will refuse to start when you tap or click the mouse. This happens because you still need to activate click input for your game.

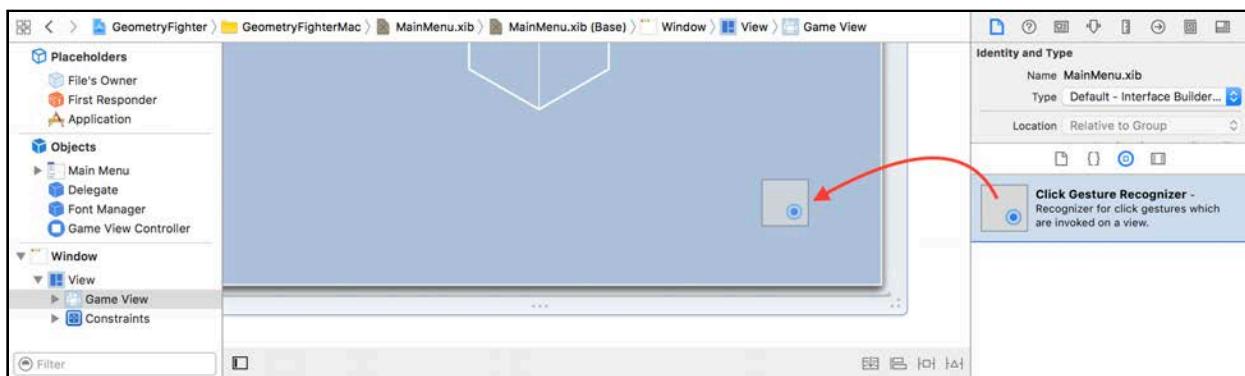
Adding mouse input

To enable mouse input for your game you need to make use of a **click gesture recognizer**.

Adding a click gesture recognizer

Select the **MainMenu.xib** again.

Find the **Click Gesture Recognizer** under the Object Library. Then, drag and drop one into your **Game View**.



Connecting the gesture recognizer

You now need to connect the gesture recognizer to the game view controller.

Enable the assistant editor and select **GameViewController.swift**.

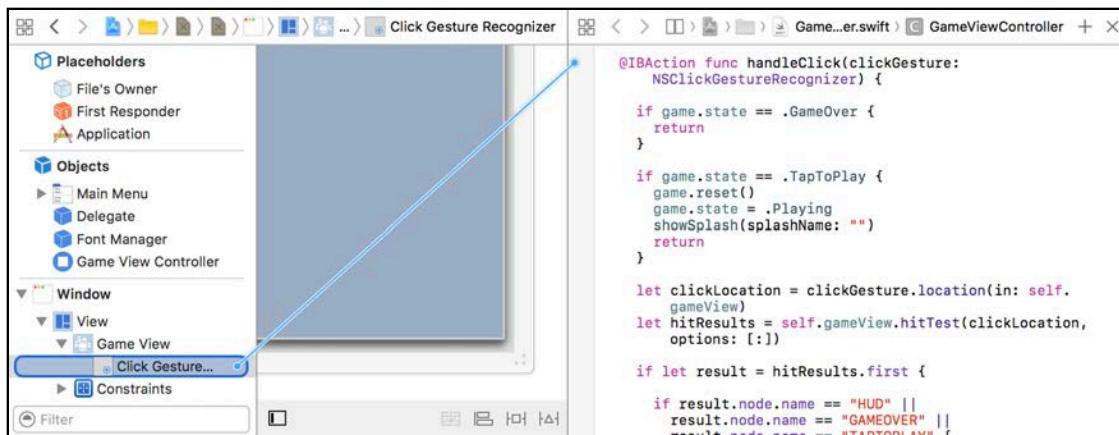


Scroll down to the spot where you see the following line of code:

```
@IBAction func handleClick(clickGesture: NSClickGestureRecognizer) { ... }
```

This function handles the click gesture event, but you still need to connect it to **MainMenu.xib**.

Drag and drop the `@IBAction` connector into the **Click Gesture Recognizer**.



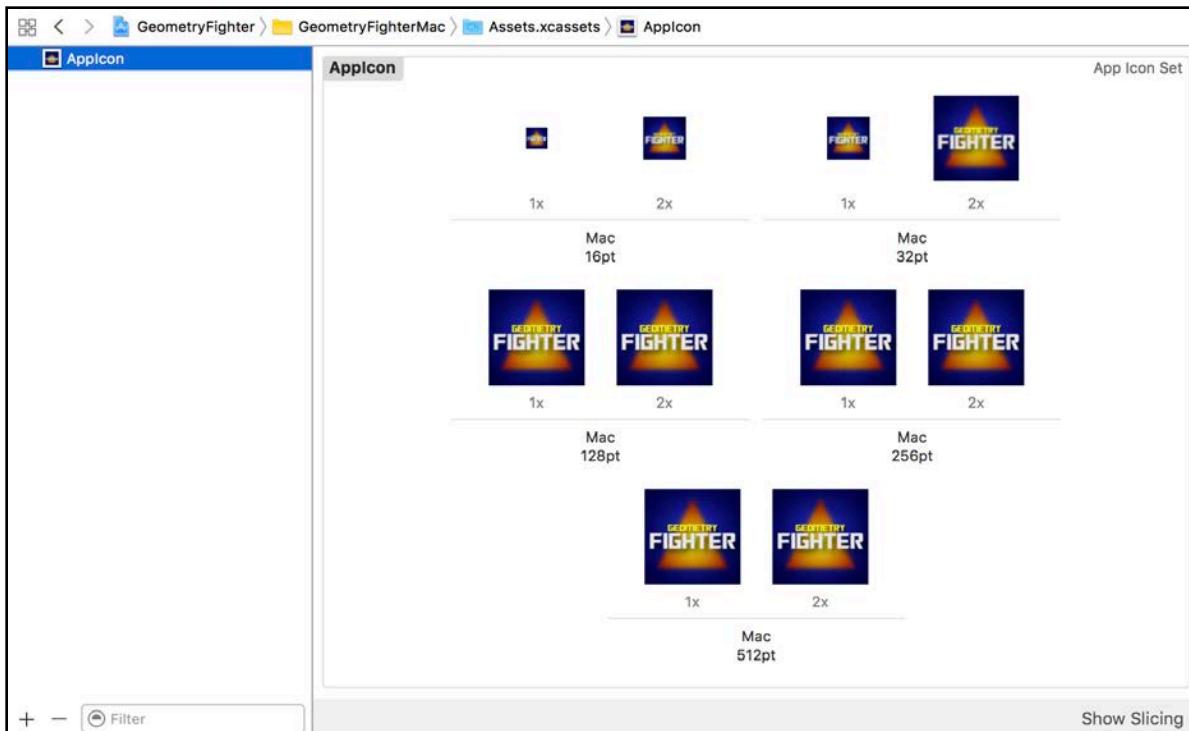
Adding final touches

Your macOS game is almost done! You just need to make it look a bit more attractive by adding the AppIcons.

Note: You'll find all the required icons under the **resources/AppIcon/** folder.

Select **Assets.xcassets** under the project navigator, then select **AppIcon**.

Drag and drop all the **AppIcon** images from Finder into Xcode under the AppIcon section.



Build and run your game one final time:



Grab your mouse and vaporize those evil shapes! :]

Note: You can find the final working project of the game under the **projects/final/GeometryFighter/** folder.

Where to go from here?

Congratulations! Now you know just how easy it can be to create a SceneKit game for macOS.

Before moving onto the next chapter, take a look at what you learned:

- **macOS Game Template:** You learned how to create a macOS SceneKit game from scratch.
- **macOS Target:** You learned how to add a macOS target to an existing iOS game project.
- **Shared Files:** You learned how to create a shared group containing all the files shared between multiple targets.
- **SCNView:** This @IBOutlet property has to be defined inside the game view controller, and has to be connected to the game view inside the **MainMenu.xib** window.

- **Click Gesture Recognizer:** To get your game to respond to gestures, you need to add gesture recognizers inside the game view. You also need to connect the recognizers to event handlers inside the game view controller.

Take a quick break. You've earned it! When you're done, meet me in the next chapter to find out how to take another existing iOS game and get it ready to run on tvOS!

Chapter 17: tvOS Games

Chris Language

If you're like me, you love playing games on the latest next-generation consoles. Can't you just picture yourself immersed in the beautiful graphics, the stunning sound and the awesome 60 frames per second gameplay action on your massive 80-inch, super-high-definition display connected to your Apple TV?

Wait, what? *Apple TV*?

Yep — SpriteKit and SceneKit are now fully supported on tvOS. There's nothing stopping you from porting your hit iOS game for those console lovers out there! :]

In this chapter, you'll learn how to take an existing iOS game — Breaker — and turn it into something that'll run on the Apple TV.

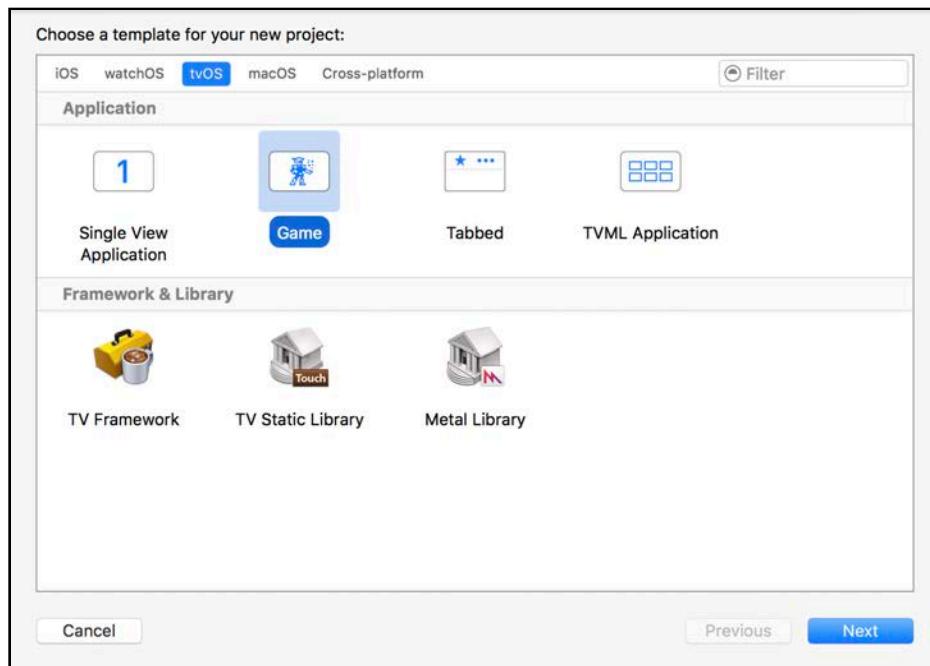
So what are you waiting for? Time to get to work!

Getting started

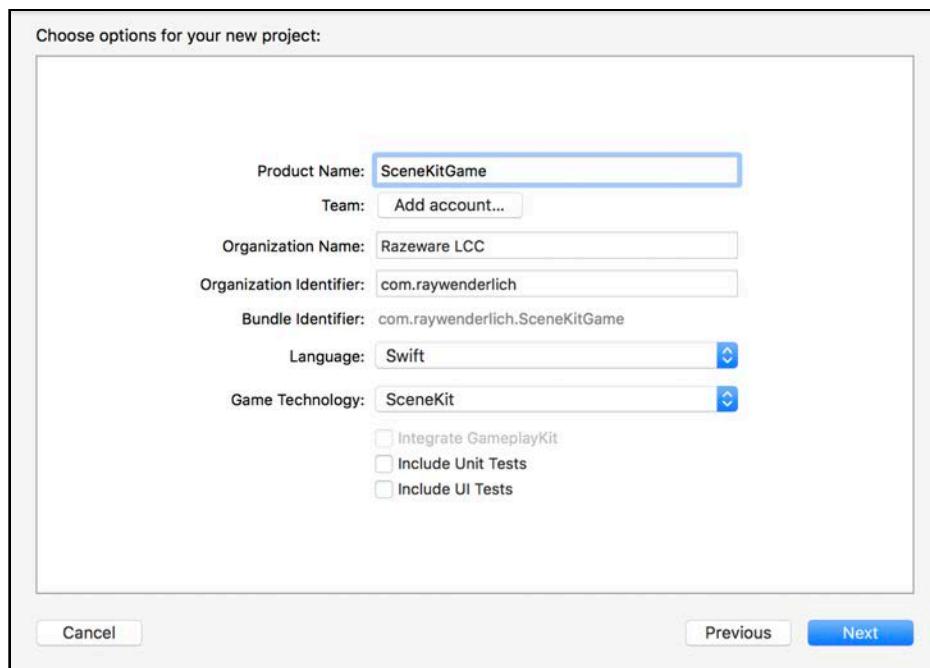
Before you start porting your game, you'll create a basic SceneKit project for tvOS, from scratch. You'll also learn the basics of navigation on the Apple TV.

Open Xcode and start by creating a new project.

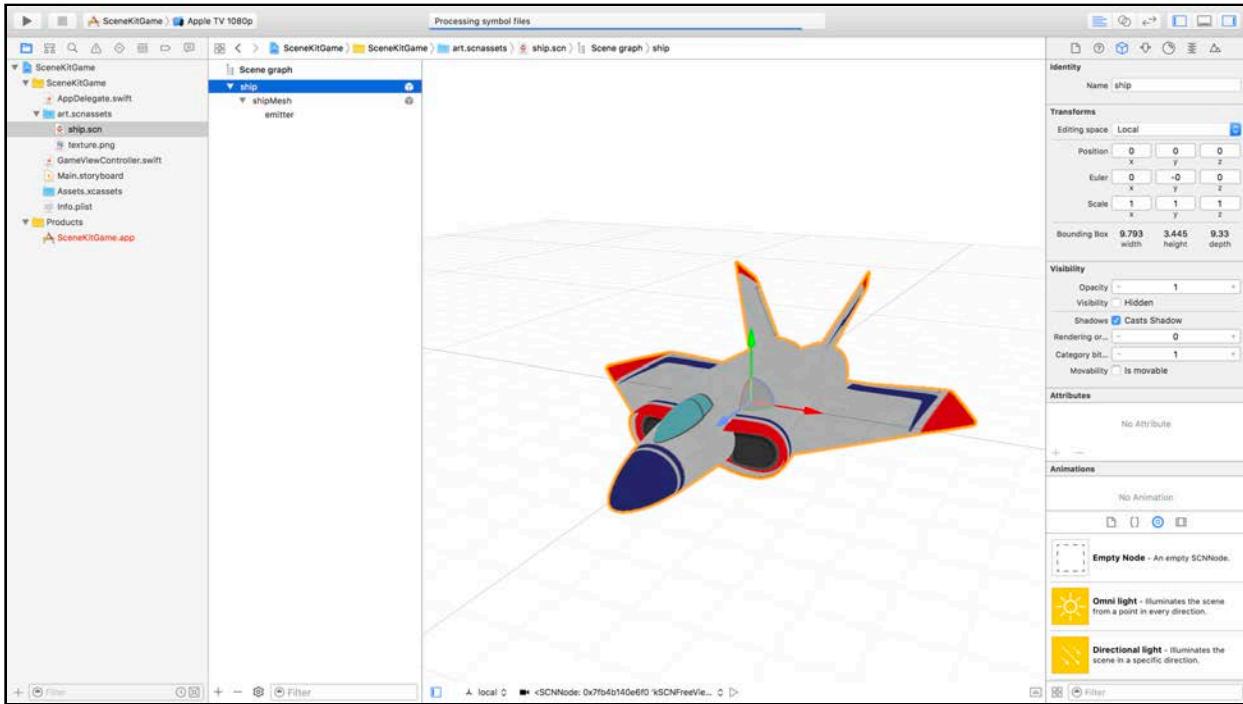
Choose **tvOS** for the platform and select the **Game** project for the template. Click Next to continue.



For the Product Name, type **SceneKitGame**. Then, select **Swift** for the Language and **SceneKit** for the Game Technology. Don't worry about **Unit** and **UI Tests**, just click **Finish** to complete the project creation process.

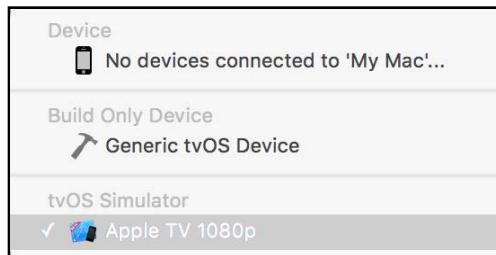


The generated project looks almost identical to a typical iOS SceneKit game project; that's because tvOS inherits a lot of the underlying technologies from iOS.

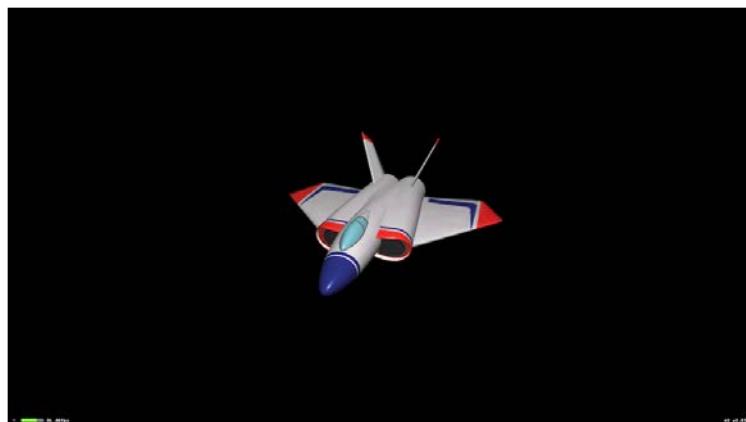


Time to take your tvOS game for a little test drive.

Select **SceneKitGame > tvOS Simulator > Apple TV 1080p** as your **Active Scheme**:



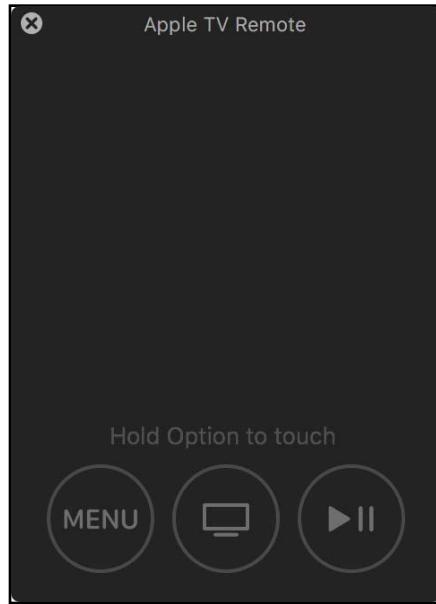
Build and run your project. The tvOS simulator starts, and your game pops up with the traditional SceneKit spinning model:



Congratulations! You just created your first tvOS game.

But wait! Notice how the game doesn't respond to any touch gestures? That's because tvOS isn't a touch-centric platform — it's *focus-centric*, which means you'll need to use the **Apple TV Remote** to navigate through the tvOS interface.

But don't worry — the simulator's got your back. Select **Hardware > Show Apple TV Remote**. That opens a nice little remote control for you:



Take note of the following features of the remote:

- **Menu button:** Use this button to navigate back to where you came from. You need to make sure you support this behavior inside your game.
- **Home button:** Use this button to go straight to your home screen, similar to how the Home button works in iOS.
- **Play/Pause button:** Use this to play and pause video or audio content. You'll have to add code to react to this button if you want to use it.
- **Touch Click:** Click inside this area to select the currently focused element, thus performing a forward navigation. You need to make sure you maintain this behavior inside of your game.
- **Touch Move:** To perform a touch gesture, you have to hold down the **Option** key while moving over the touch area. This will control the focus point and generate touch gesture events inside your game, just like in iOS.

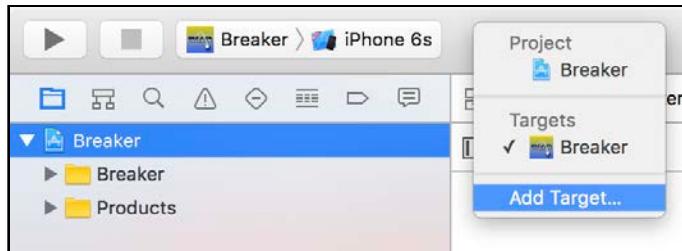
Porting to tvOS

Now that you know the basics, it's time to move on to something more advanced. Instead of using the basic old SceneKit starter template project, you'll be using a finished game project from Breaker. In this section, you'll add support for tvOS.

Note: You can find the starter project for this chapter under the **projects/starter/Breaker/** folder. Go ahead and load the project before you continue with the next section.

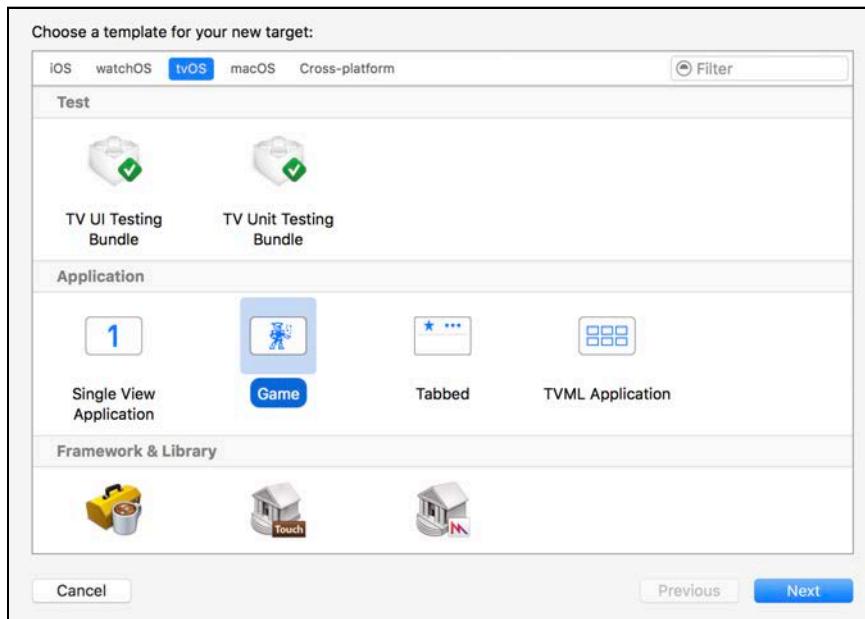
Adding a tvOS target

Start off by adding an additional target to your existing game project. With the project root element selected under the project navigator, click **Breaker**, on the right side, and add a new target.

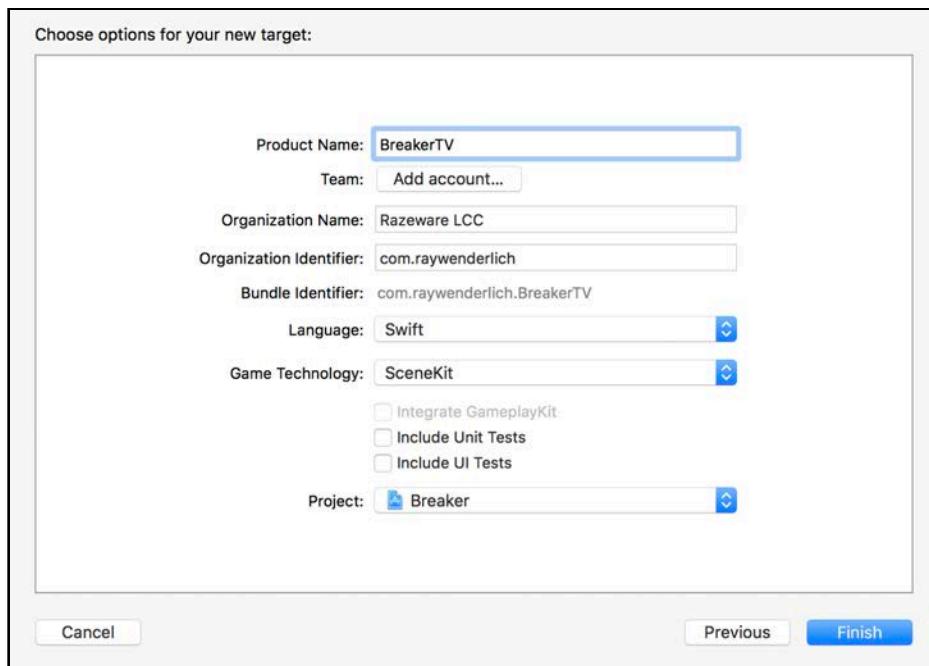


When the popup menu appears, select the **Add Target...** option. This lets you choose the platform of your choice along with a project template.

Choose **tvOS** for the platform. Then, select **Game** in the Application section for the project template.

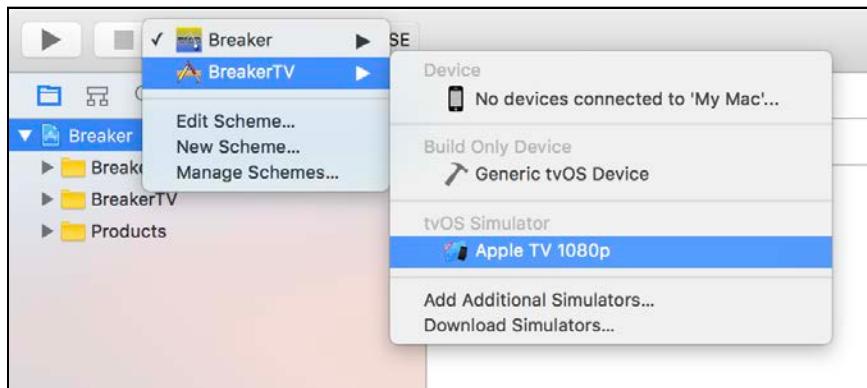


Type **BreakerTV** as your Product Name. Then, select **SceneKit** for the Game Technology. Also uncheck the options to include **Unit Tests** and **UI Tests**; you don't need those for the new tvOS target. When you're done, click **Finish** to complete the project creation.



You'll see a new **BreakerTV** group added to the project. It contains all the usual suspects you'd find under a typical SceneKit game template project.

Select **BreakerTV > tvOS Simulator > Apple TV 1080p** as your **Active Scheme**:



Do a quick build and run to see how the game looks:



You should see the basic SceneKit demo game template start, running on a tvOS simulator.

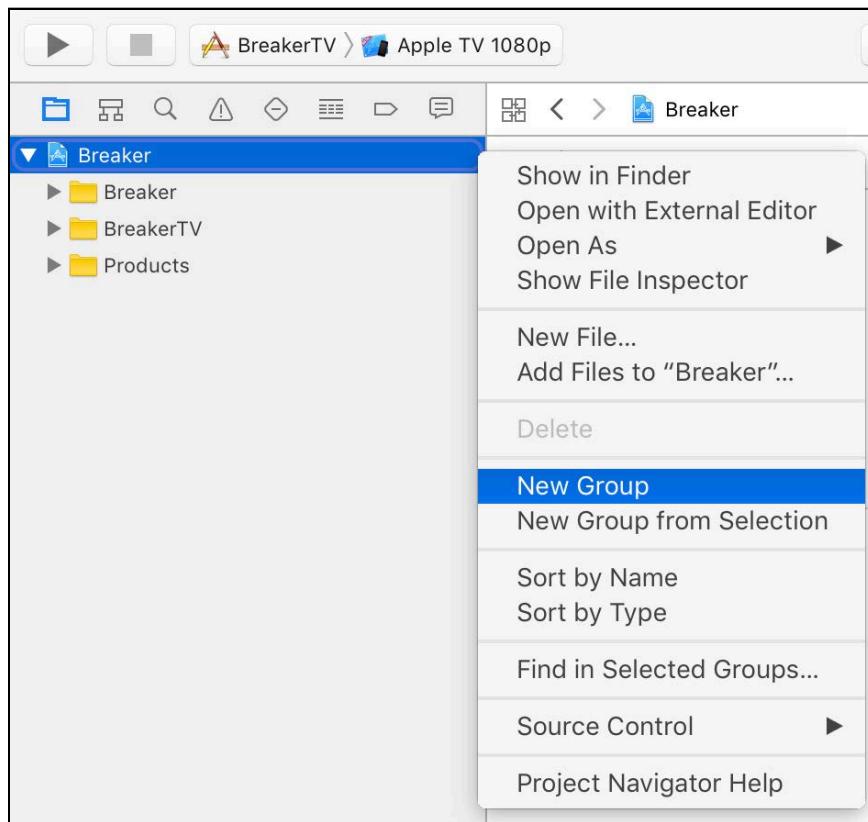
Were you expecting to see Breaker? Unfortunately, things aren't *quite* that easy. You only added an additional target platform to the existing iOS game project using the basic SceneKit game template. There are still a few steps you need to follow before the actual iOS game will run on tvOS.

Sharing content between targets

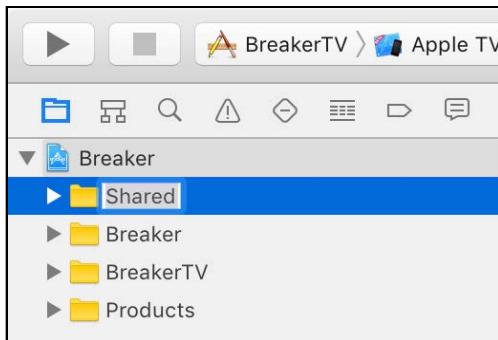
The next section focuses on sharing common content between multiple platform targets. Luckily, there's already a lot of code and resources that can be shared between iOS and tvOS. To keep things organized, you'll create a special shared group specifically for these files.

Creating a shared group

Start by creating a new **Shared** group. Right-click on the project root element **Breaker** and select **New Group**:



This creates a new group for your project. Name the new group **Shared**:

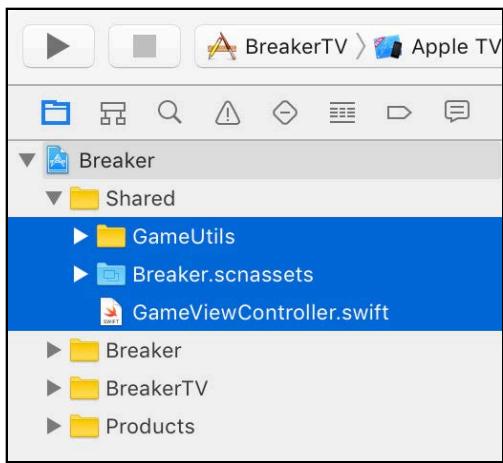


Now, move the common shared files into this new group.

Expand the original Breaker iOS group and select the following elements while holding down the **Command** key:

- **GameUtils**
- **Breaker.scnassets**
- **GameViewController.swift**.

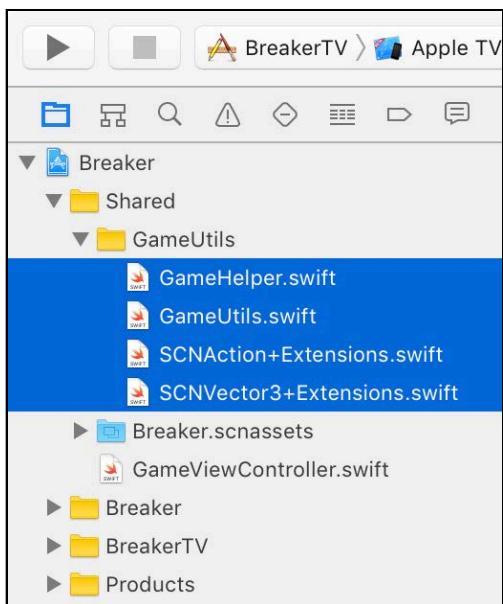
Drag and drop these items into the new **Shared** group. Your project navigator will now look like this:



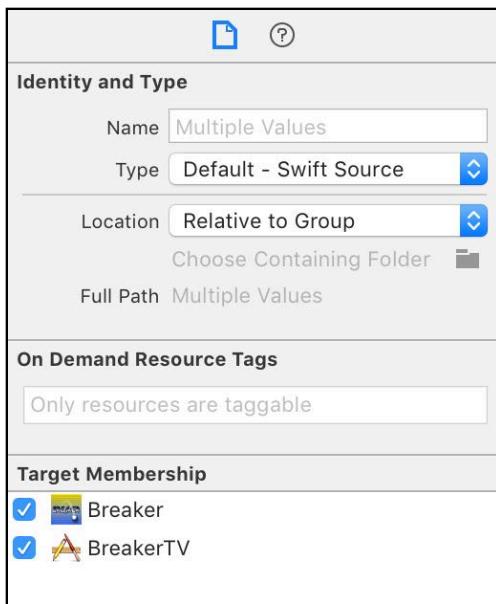
Sharing files between targets

Now you need to configure the **Target Membership** for all shared files to target both iOS and tvOS.

Select all the files under **Breaker/Shared/GameUtils** while holding down the **Shift** key:



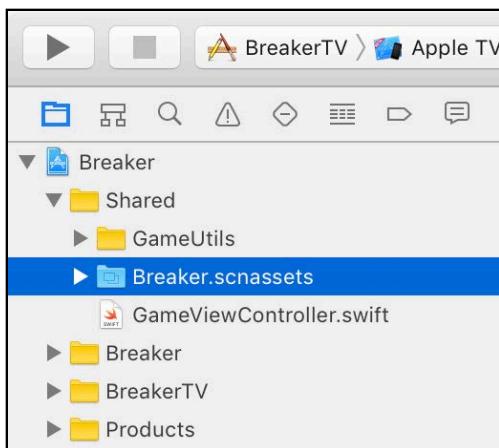
Select the File Inspector on the right, then check **BreakerTV** under Target Membership:



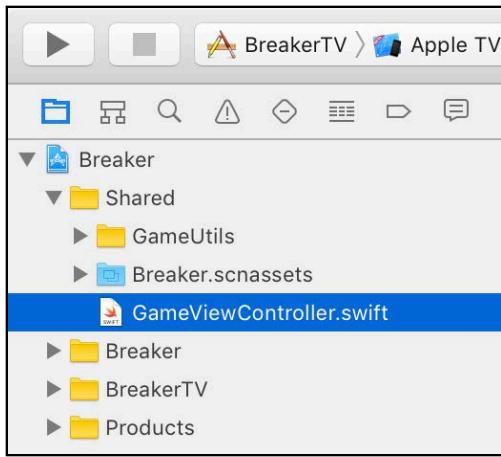
The selected files are now shared with both the iOS target and the tvOS target. Sweet!

Now repeat this task for the rest of the files under the Shared group:

First, select **Breaker/Shared/Breaker.scnassets**. Then select the File Inspector on the right and check **BreakerTV**.



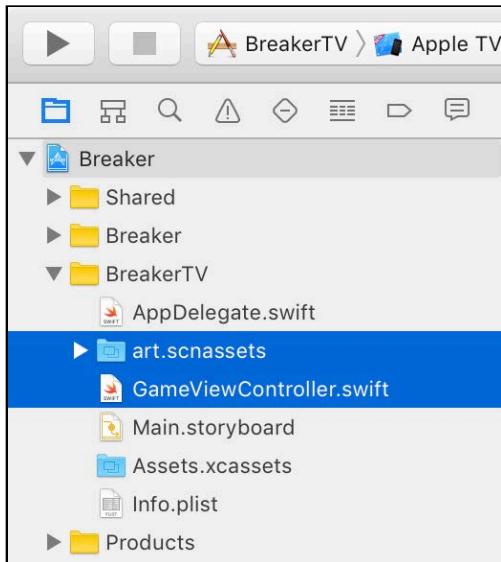
Next, select **Breaker/Shared/GameViewController.swift**. Then select the File Inspector on the right and check **BreakerTV**.



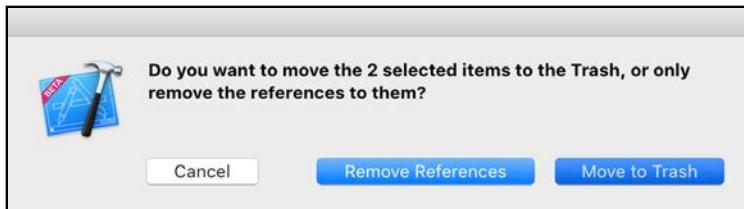
Cleaning up the project

You now have a single **GameViewController.swift** file shared between both iOS and tvOS. Of course, this will clash with **GameViewController.swift** under the BreakerTV group. You'll need to take care of that next, along with a few other issues.

Select **BreakerTV/art.scnassets** and **BreakerTV/GameViewController.swift**. Then delete both of them:



When prompted, select **Move To Trash**:



Adding platform specific code

Now that both targets share a single **GameViewController.swift** file, you need to add some platform specific code for each target.

Open **GameViewController.swift**, which is listed under the Shared group. Add the following code snippet to the end of `setupNodes()`:

```
#if os(tvOS)
    scnView.pointOfView = horizontalCameraNode
#endif
```

When you compile against the tvOS target scheme, the default point of view will be set to the horizontal camera node, because tvOS doesn't support multiple orientations. Besides, trying to rotate your massive flat screen on its side would really be silly! :]

Next, mark `shouldAutorotate`, `prefersStatusBarHidden` and `viewWillTransition()` for iOS only, by adding `#if os(iOS) ... #endif` around each as follows:

```
#if os(iOS)
    override var shouldAutorotate: Bool {
        ...
    }

    override var prefersStatusBarHidden: Bool {
        ...
    }

    override func viewWillTransition(to size: CGSize, with coordinator: UIViewControllerTransitionCoordinator) {
        ...
    }
#endif
```

You only want iOS-specific code to compile when compiling against the iOS target scheme; the preprocessor directives make that happen.

Touch location and sensitivity

Out of the box, Breaker translates pretty well to tvOS when it comes to touch controls. The saving grace is due the fact that the initial `touchesBegin()` location gets stored. All subsequent `touchesMoved()` locations are then calculated relative to

that stored location. The result works pretty much the same as a typical trackpad on a MacBook.

When dealing with iOS and a touch screen, the starting location translates relatively to same location where your finger touches the screen. This behavior is not quite the same when dealing tvOS and an Apple TV Remote. No matter where you place your finger on the designated touch area on the remote, the `touchesBegin()` location will always report (x: 960, y: 540) as the initial location. This location translates exactly to the center point of a Full HD 1080p display. To track the actual movement, you need to include this initial location in all the subsequent `touchesMoved()` location calculations.

Luckily Breaker did that already. Phew! :]

The coast is not clear yet, because there's another little problem lurking. The tracking sensitivity is way too sensitive on tvOS compared to iOS, this results in the game being almost completely unplayable.

To solve the problem, find the following line of code in `GameViewController`:

```
paddleNode.position.x = paddleX +  
    (Float(location.x - touchX) * 0.1)
```

Then replace it with the following:

```
#if os(iOS)  
    paddleNode.position.x = paddleX +  
        (Float(location.x - touchX) * 0.1)  
#elseif os(tvOS)  
    paddleNode.position.x = paddleX +  
        (Float(location.x - touchX) * 0.01)  
#endif
```

This introduces platform specific code that simply makes sure that the paddle position is calculated with a `0.01` precision factor on tvOS, compared to the `0.1` precision factor on iOS. Problem solved! :]

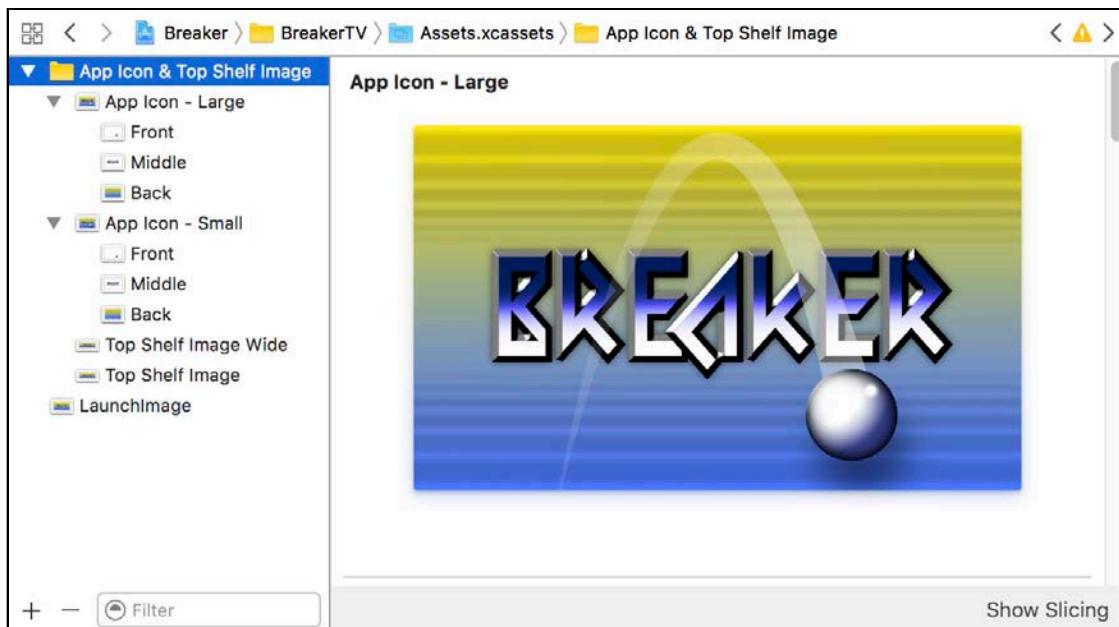
Top-shelf and App icons

Your game is basically done — the only thing left is to add some polish. You'll do that by adding a tvOS top-shelf image, launch image and an app icon.

Note: You can find the required resources for this section under the **resources** folder of the starter project for this chapter.

Open **BreakerTV/Assets.xcassets** and expand the **App Icon & Top Shelf Image**.

Drag and drop each corresponding image from the resources folder into the correct project asset image. Once done, you should have something that resembles the following:



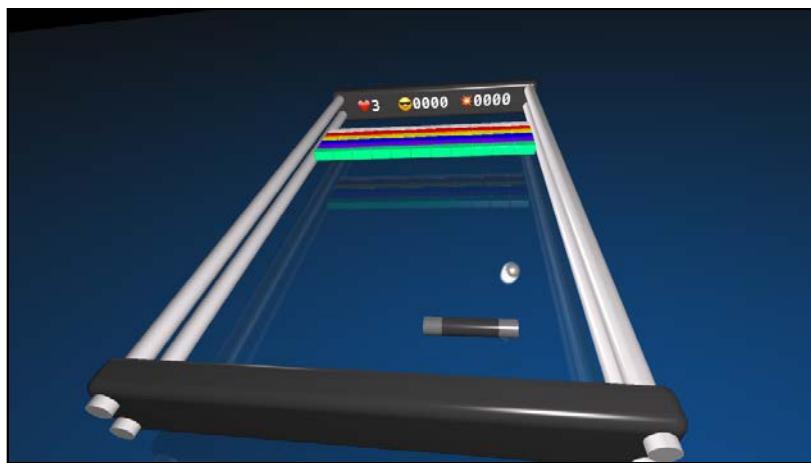
The app icons consist of multiple layers divided into a back, middle and front section. Drag your mouse around to see a preview of the 3D image that's created using this layered effect. Cool!

Build and run, then press the menu button to see the Apple TV home screen:



If this was one of your first applications for tvOS, your game icon would most likely appear inside the top-shelf area. Think of the top-shelf as a special space where the users can place all their most favorite selection of applications and games. Only when your game is placed in this top-shelf area and the user has your game icon in focus, that's when the user will be able to see your games top-shelf image on screen.

Click the touch area on the TV remote to start your game.



Excellent! You're all done, and your tvOS game is looking mighty fine! :]

Note: Slow performance while running in the tvOS simulator is expected. To experience the game in its full glory, you'll need an actual Apple TV to test with.

Where to go from here?

Congratulations — you now know just how easy it can be to create a SceneKit game for tvOS. You can find the final project for this chapter under the **projects/final/** **Breaker/** folder.

To recap what you covered in the chapter:

- **tvOS Game Template:** You learned how to create a tvOS SceneKit game from scratch.
- **Apple TV Remote:** You learned about the Apple TV Remote and how to use it with the Apple TV simulator.
- **tvOS Target:** You learned how to add a tvOS target to an existing iOS game project.
- **Shared Files:** You learned how to create Shared group containing all the files shared between multiple targets.
- **GameViewController.swift:** You learned how to share a single controller between multiple platforms, using `#if os(tvOS)` and `#if os(iOS)` to target code at a specific platform.

I can't wait to see what games you port to tvOS!

Chapter 18: watchOS Games

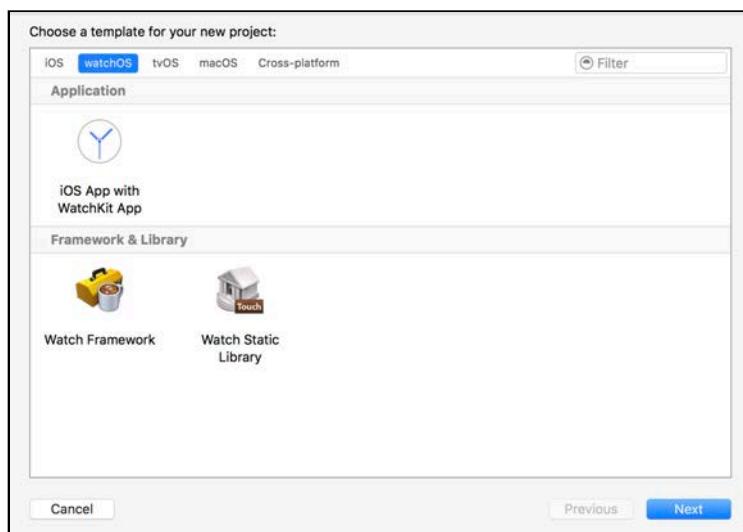
Chris Language

Not to be outdone, the Apple Watch also has support for SpriteKit and SceneKit in watchOS 3. Now you can take the amazing game action on your 80-inch TV and condense that awesomeness into 2D and 3D games for the Apple Watch.

In this chapter, you'll learn how to create your very own watchOS game from the existing iOS game Geometry Fighter.

Getting started

Wondering how to create a watchOS SceneKit game from scratch? Well, it's not quite as easy as iOS or tvOS — there's no SceneKit Game project template. Boo. :[



But where there's a will, there's always a way! You'll start off by creating an iOS SceneKit game project, then you'll add support for watchOS.

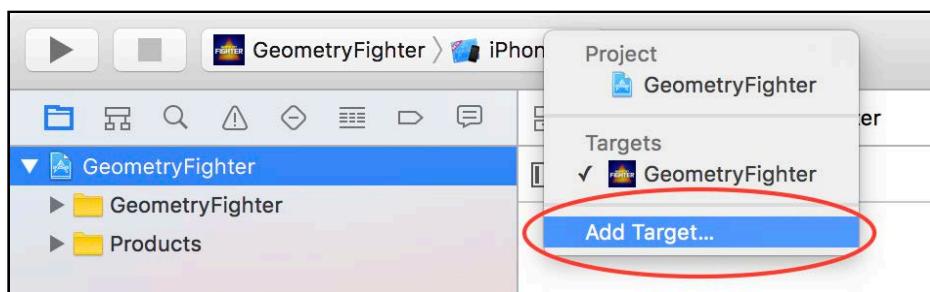
Adding watchOS support

Instead of using the basic old SceneKit starter template project, you'll be using a finished game project from Geometry Fighter.

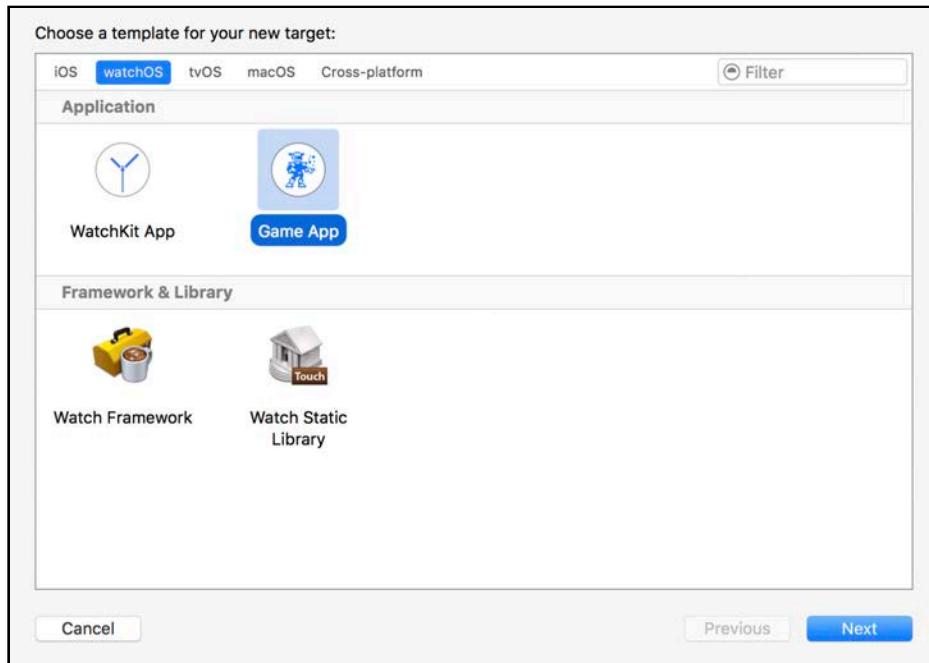
Note: You can find the starter project for this chapter under the **projects/starter/GeometryFighter/** folder. Load up the project before you continue with the next section.

Adding a watchOS target

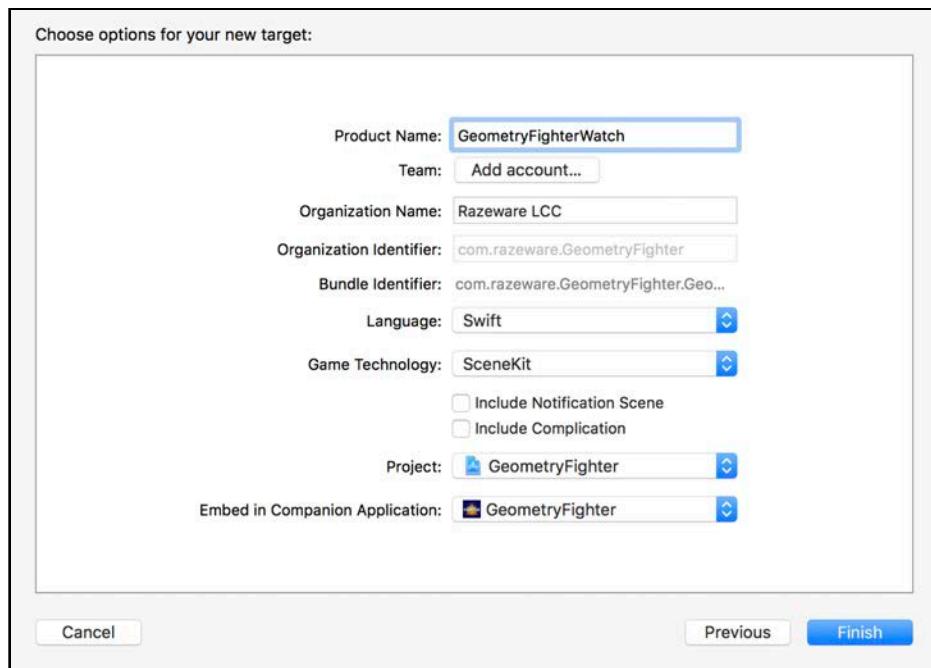
Start off by adding an additional target to your existing game project. With the project root element selected under the project navigator, click **GeometryFighter**, on the right side, and select **Add Target...** from the popup.



Choose **watchOS** for the platform, and choose **Game App** for the project template.



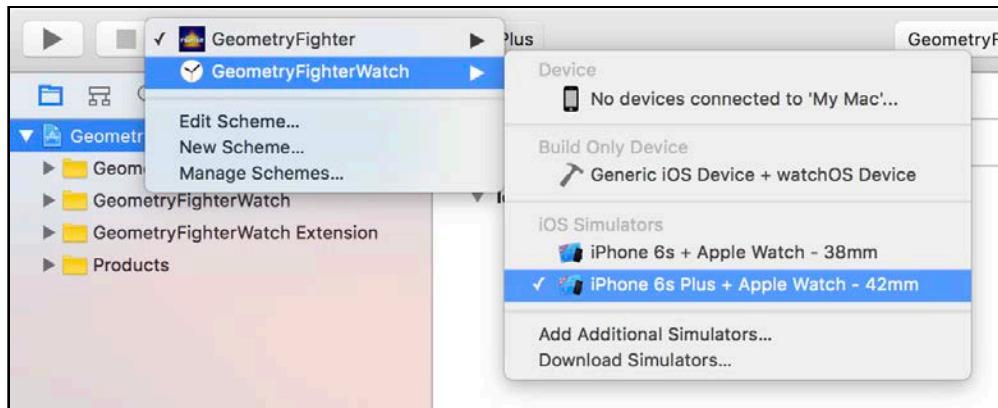
Type **GeometryFighterWatch** for the Product Name. Then, select **SceneKit** for the Game Technology. Also, uncheck the options to include **Unit Tests** and **UI Tests**; for the new watchOS project, you won't need those. When you're done, click **Finish** to complete the project creation.



There are two additional groups in your project:

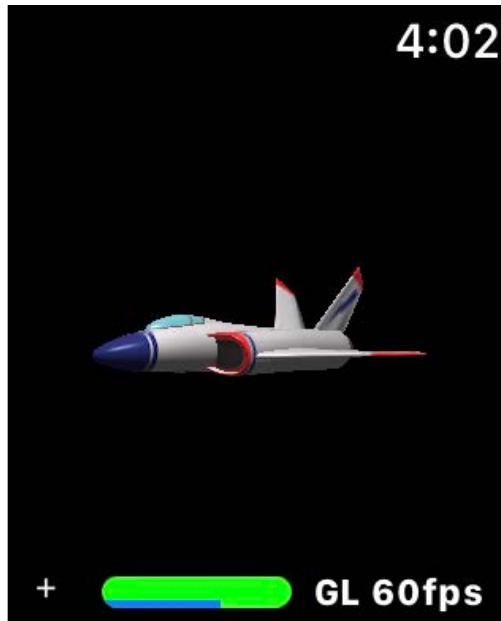
- **GeometryFighterWatch**: Contains **Interface.storyboard** and **Assets.xcassets** files.
- **GeometryFighterWatch Extension**: Contains **InterfaceController.swift**, which is essentially your GameViewController and an **art.scnassets** folder which contains your Game scene and other resources.

Select **GeometryFighterWatch > iPhone 6s Plus + Apple Watch - 42mm** as your **Active Scheme**:



The next time you build and run, Xcode will start an iPhone simulator along with a 42 mm watchOS simulator.

Do a quick build and run; you will see the basic SceneKit demo game template start, running on a watchOS simulator:



Well done, you just created your very first watchOS SceneKit game! :]

Were you expecting to see Geometry Fighter? Unfortunately, things aren't that easy. You only added an additional target platform to the existing iOS game project using the basic SceneKit game template. There are still a few steps you need to follow before the actual iOS game will run on watchOS.

Note: Inspect the generated project files to get a better understanding of the main differences between a typical iOS game project versus a watchOS project. Take particular notice of **InterfaceController.swift**, and **Interface.storyboard**. These are your GameView and GameViewController.

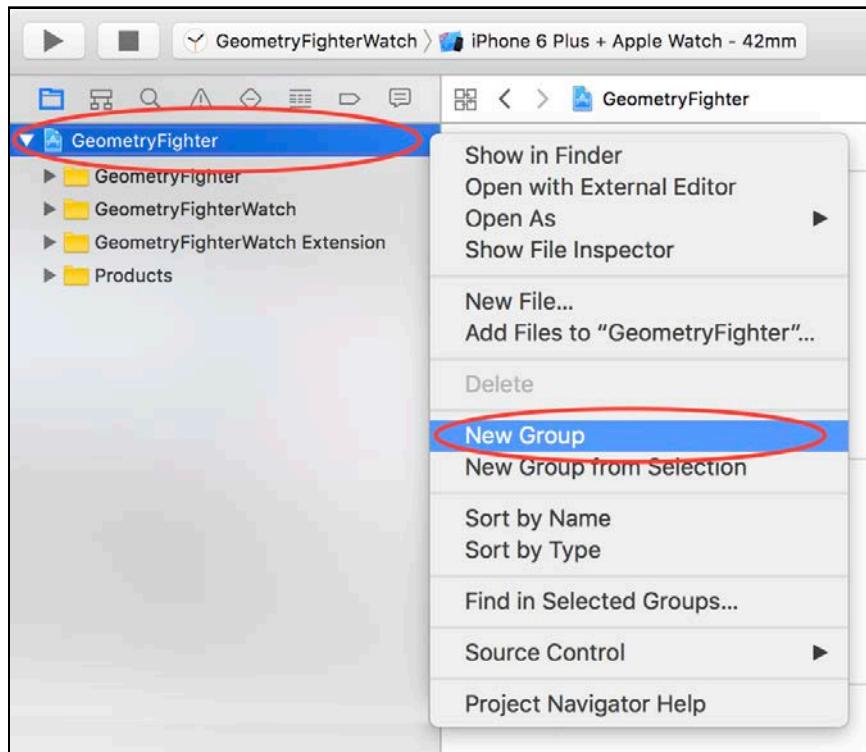
Sharing content between multiple targets

The next section focuses on sharing common content between multiple platform targets. Luckily there's already a lot of code and resources that can be shared between iOS and watchOS. You'll create a special shared group specifically for these files.

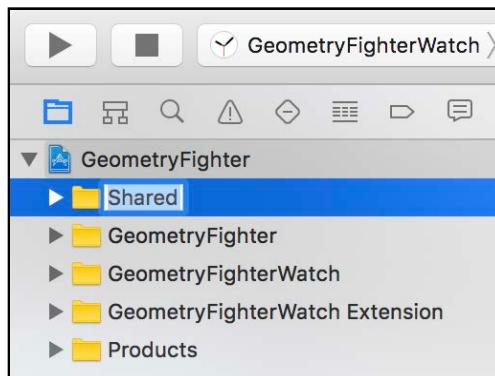
Creating a shared group

Start by creating a new **Shared** group.

Right-click on the project root element **GeometryFighter** and select **New Group**. This will create a new group for your project.



Name the new group **Shared**:

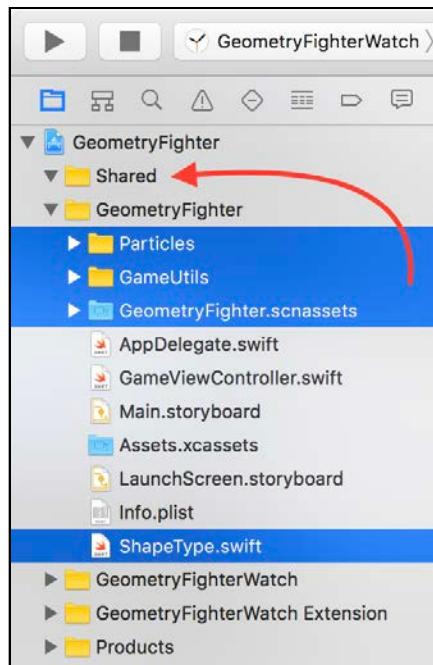


Now you need to move the common shared files into this new group.

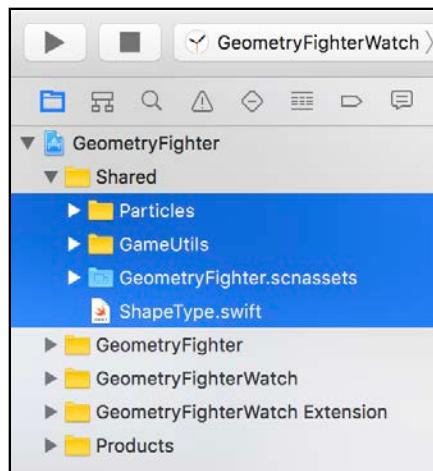
Expand the original iOS group **GeometryFighter** and select the following elements while holding down the **Command** key:

- **Particles**
- **GameUtils**
- **GeometryFighter.scnassets**
- **ShapeType.swift**

Drag and drop these elements into the new **Shared** group.



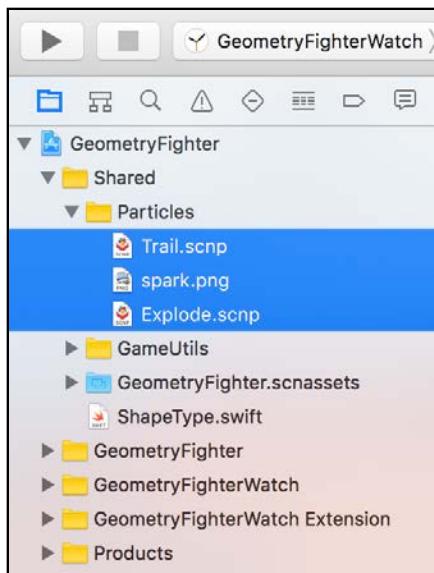
Your project navigator will look like the following when you're done:



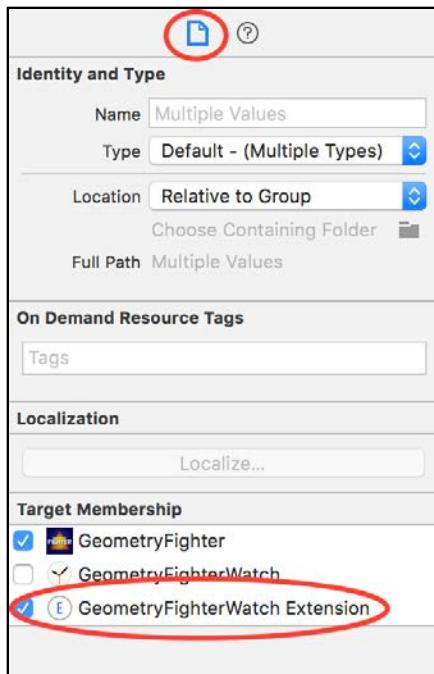
Sharing files between multiple targets

Now you need to configure the **Target Membership** for all the shared files to target both iOS and watchOS.

Select all files under **GeometryFighter/Shared/Particles** while holding down the **Shift** key:



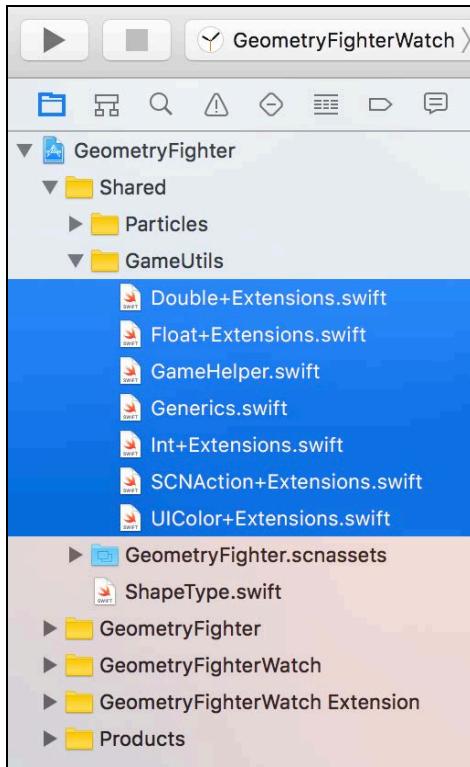
Select the File Inspector on the right, then check **GeometryFighterWatch Extension** under **Target Membership**:



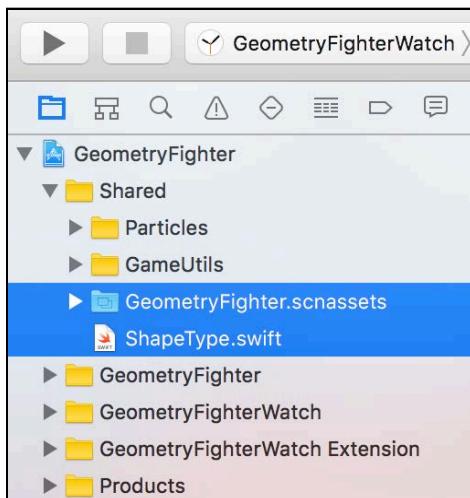
The selected files are now shared with both the iOS target and the watchOS target.

Now you need to perform the same task for all the other files under the Shared group.

Select all the files in **GeometryFighter/Shared/GameUtils**. Then select the File Inspector on the right, and check **GeometryFighterWatch Extension**.



Finally, select **GeometryFighter/Shared/GeometryFighter.scnassets** and **GeometryFighter/Shared/ShapeType.swift**. Then select the File Inspector on the right, and check **GeometryFighterWatch Extension**.

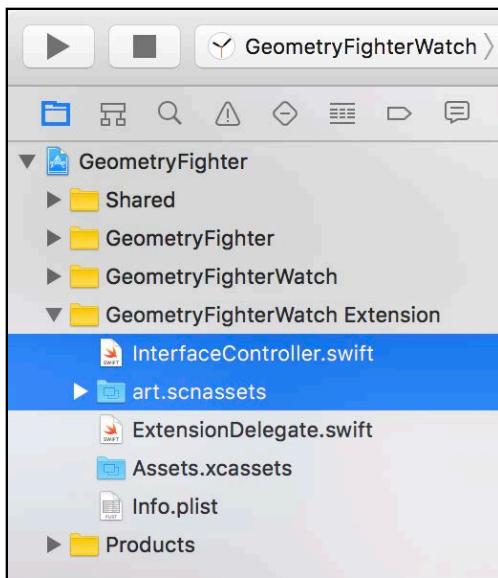


Adding the interface controller

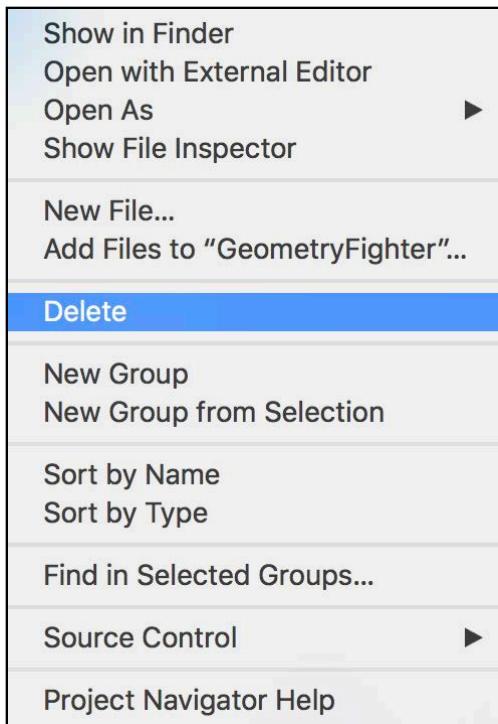
Before you can add your own interface controller, you need to remove some unwanted files.

Cleaning up the project

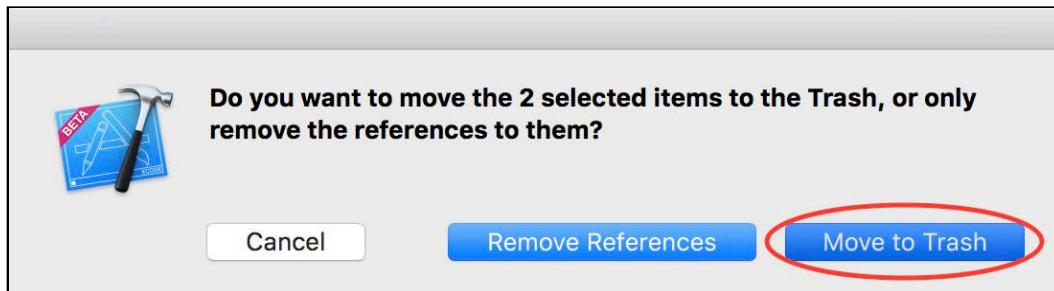
Select **InterfaceController.swift** and **art.scnassets**.



Then, right-click the files and select the **Delete** option.



When prompted, select **Move to Trash** to permanently remove the files from your project:

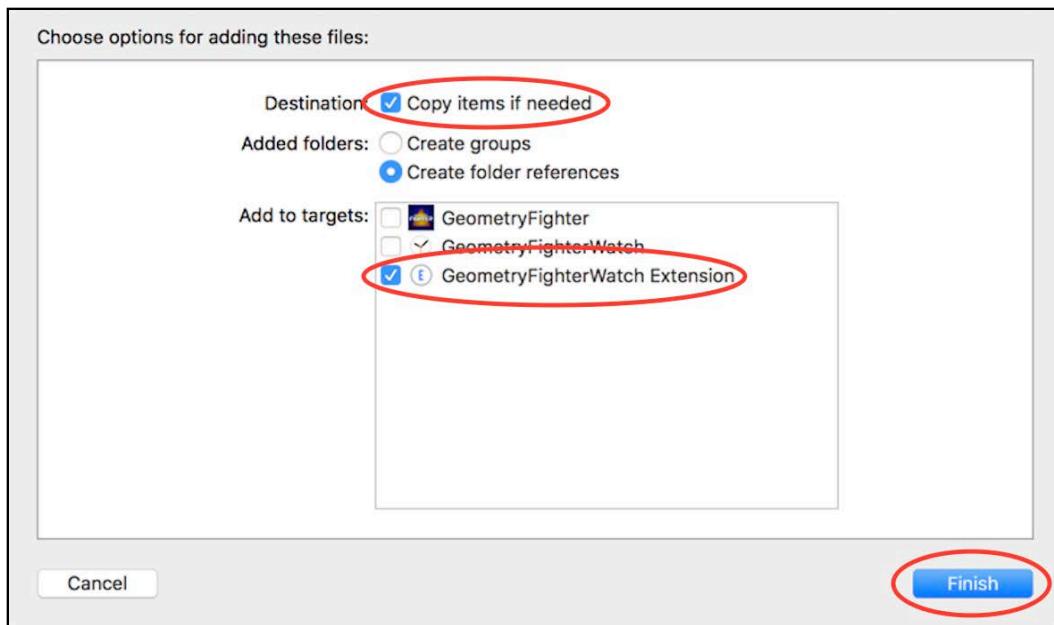


Adding the interface controller

Now you need to add the new **InterfaceController.swift** to the watchOS target. This file contains almost exactly the same code as the **GameViewController.swift** file targeted at iOS.

There's a ready made **InterfaceController.swift** file waiting for you under the **resources/source** folder. Drag and drop the file from Finder into your Xcode project.

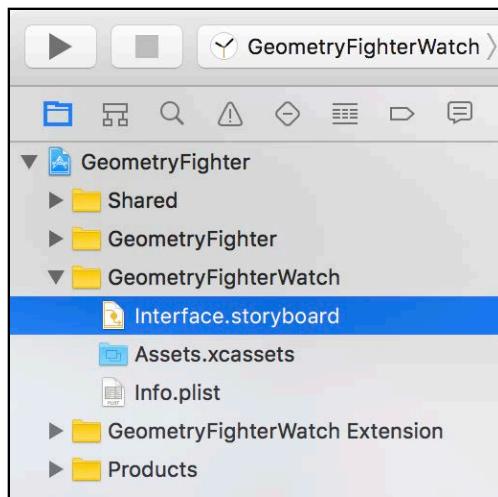
Make sure you select **Copy items if needed**. Select only **GeometryFighterWatch Extension** as a target. Then, click **Finish** to import the new file into your project.



Connecting the story board

Now that you have a new interface controller, you need to connect it to the Interface storyboard.

Select **Interface.storyboard** under the project navigator.



Enable the assistant editor and navigate to **InterfaceController.swift**. Scroll to the spot where you see the following line of code:

```
@IBOutlet var scnInterface: WKInterfaceSCNScene!
```

The **WKInterfaceSCNScene** is the WatchKit equivalent to the **SCNView** in the iOS target; this gives you access to the SceneKit view on the storyboard.

You now need to connect the `scnInterface` outlet to the SceneKit Scene interface inside the storyboard.

Drag and drop the `@IBOutlet` connector into the **SceneKit Scene** control.



Build and run your game; you'll notice the game refuses to start when you tap on the screen. That's because you still need to activate touch input for your game.

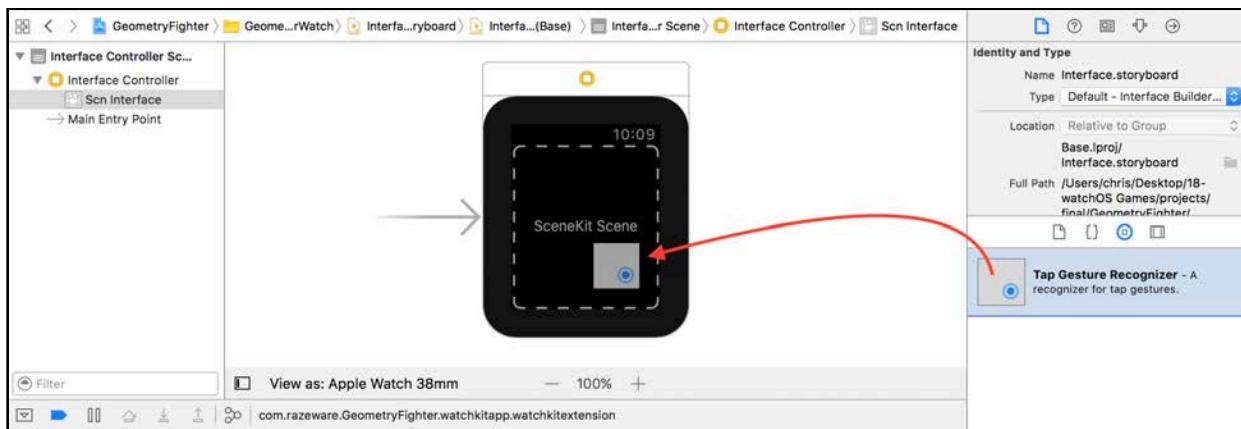
Adding touch input

To enable touch input for your game, you need to use a tap gesture recognizer.

Adding a tap gesture recognizer

Select the **Interface.storyboard** again.

Find the **Tap Gesture Recognizer** under the Object Library. Then, drag and drop a tap gesture recognizer into your SceneKit Scene, inside the storyboard.



Connecting the gesture recognizer

You now need to connect the gesture recognizer to the interface controller.

Enable the assistant editor, and open **InterfaceController.swift**. Scroll down to the spot where you see the following line of code:

```
@IBAction func handleTap(tapGesture: WKTapGestureRecognizer) {  
    ...  
}
```

This function will handle the tap gesture event, but you still need to connect it to the storyboard.

Drag and drop the @IBAction connector into the **Tap Gesture Recognizer**.



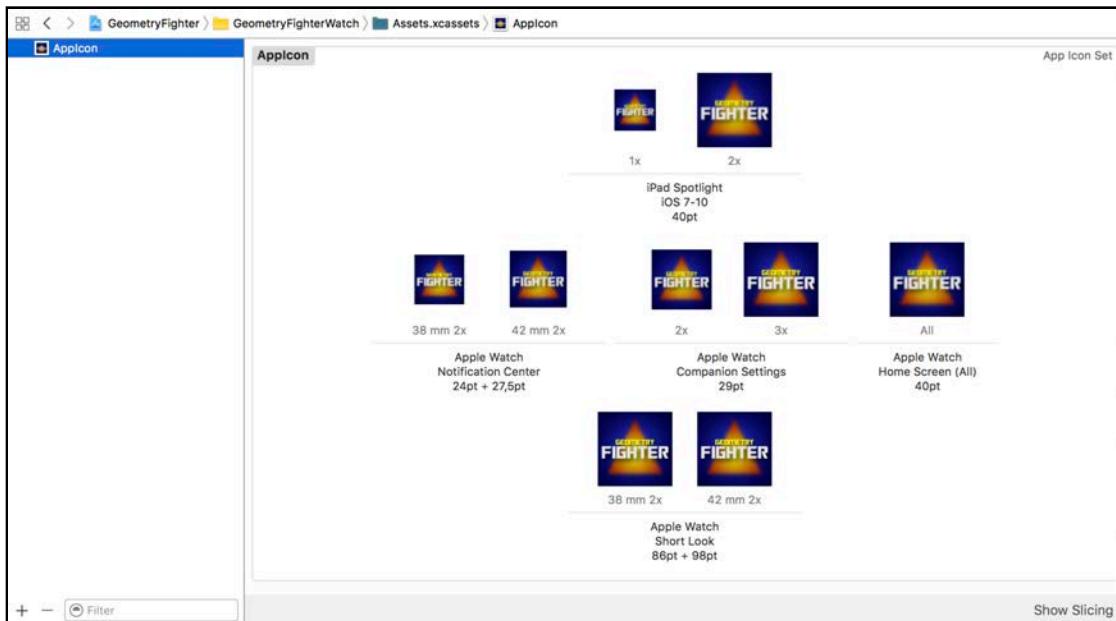
Adding final touches

Your watchOS game is almost done — you just need to polish it up by adding the app icons.

Note: You'll find all the required icons under the **resource/AppIcon** folder.

Select the **Assets.xcassets** file under the project navigator, then select **AppIcon**.

Drag and drop all the **AppIcon** images from Finder into Xcode under the **AppIcon** section. Things should look like the following when you're done:



Do a final build and run:



Sit back and enjoy your game on your wrist!

Note: You can find the final working project of the game under the **projects/final/GeometryFighter/** folder.

Where to go from here?

Congratulations — you learned how to port a game from iOS to watchOS, and what you need to *watch out* for along the way.

Let's do a quick recap of all the important bits:

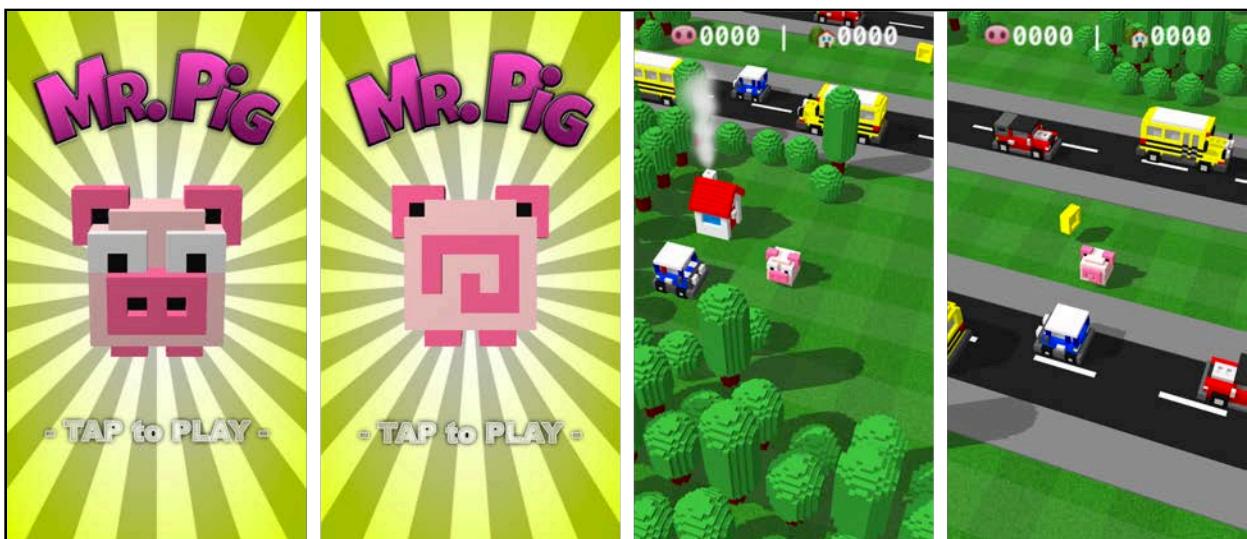
- **watchOS Target:** You learned how to add a watchOS target to an existing iOS game project.
- **Shared Files:** You learned how to create a shared group containing all the files shared between multiple targets.
- **InterfaceController.swift:** You now know this file is essentially the same as **GameViewController.swift** inside an iOS target.
- **WKInterfaceSCNScene:** This `@IBOutlet` property has to be defined inside the interface controller and has to be connected to the SceneKit Scene control inside the storyboard. It's the equivalent to a **SCNView** inside an iOS target.
- **Tap Gesture Recognizer:** To respond to gestures, you need to add gesture recognizers to your game inside the storyboard. You also need to connect the recognizers to event handlers inside the interface controller.

How about converting another game to watchOS? It should be child's play, now that you know exactly how to do it!

Section V: Advanced SceneKit

"The SceneKit Force is quite strong within you, young apprentice." (Read in a deep, heavy, asthmatic breathing voice. :])

In this section, you'll learn a few more advanced techniques, as well as apply all the skills you've learned up to this point, to creating an awesome little voxel-style game. By the end of this section, you'll know enough to take on the big Hipster Whales out there with your very own game: Mr. Pig.



This is a *Crossy Road* style game with stunning voxel graphics, a catchy tune and some cool sound effects.

The premise: Mr. Pig is out and about scouting for lost coins in a nearby park while waiting for his late afternoon tea to heat up on the stove. Unfortunately, some big bad wolf decided to build a massive mall nearby, resulting in a very busy highway straight through his lovely park.

Mr. Pig better watch his step, or he'll end up as pulled pork in the road. :] Our hero can carry quite a few coins with him, but to score, he has to deposit them at his little house.

So what are you waiting for? Get *crackling!* :]

Chapter 19: Transitions

Chapter 20: Advanced Reference Nodes

Chapter 21: Actions

Chapter 22: Advanced Collision Detection

Chapter 23: Audio

Chapter 19: Transitions

Chris Language

Getting started

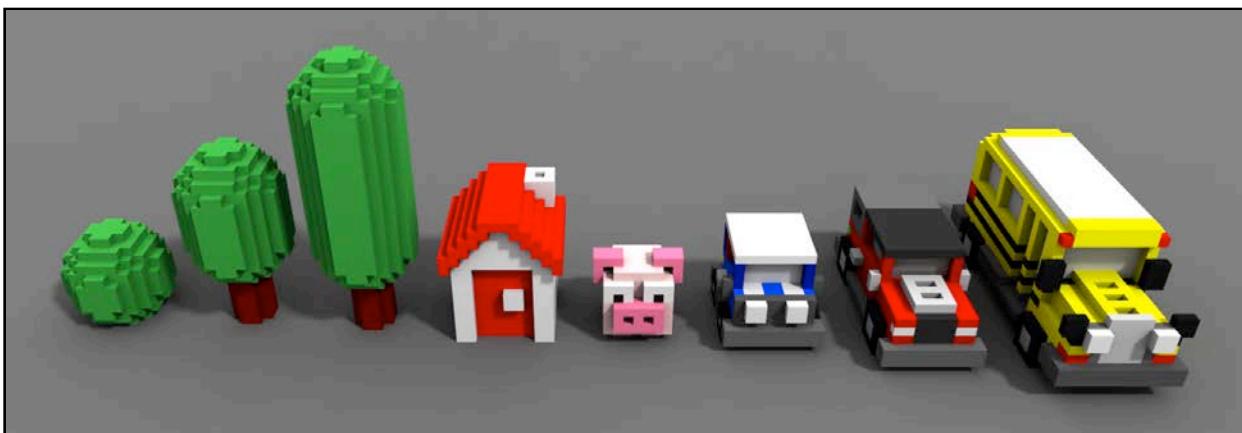
In this chapter, you'll start off by creating your game project in a slightly different way. Rather than using the SceneKit game template, you'll use the single view application template.

You'll also create the first two main scenes for Mr. Pig: one that will be your main game scene and one to be your splash scene. Later, you'll also cover how to transition from one scene to the other.

Say goodbye to building objects from scratch with primitive shapes and geometry. You're about to be rewarded!

This game will use graphics made in the popular voxel style, similar to those more recently employed in titles like *Crossy Road*, *Pacman 256* and *Shooty Skies*.

A highly skilled team of graphic artists sweated night and day to produce a small set of shiny voxel art just for your game. Without further ado, please meet the cast of your next game.



From left to right:

- **Trees:** These three little tree types will be used to fill a charming park with lush vegetation. They'll also act as obstacles, so Mr. Pig will have to think on his hooves to move past them.
- **House:** What a lovely house! This is Mr. Pig's residence and where he stores his found treasure.
- **Mr. Pig:** Meet the hero of your game — Pig, *Mr. Pig* that is. He's always on the hunt for lost treasures in the nearby park. For a swine, he's going to be rather nimble — you'll build in swiping gestures to make him jump around.
- **Vehicles:** These relentless gas guzzlers are known as Minis, SUVs and School buses. They couldn't care less about little pigs that cross the road. They've got places to go and certainly won't stop for our hero.

Note: The graphics were created with a popular authoring tool known as *MagicaVoxel*. You can download it from voxel.codeplex.com for free and play around for yourself!

Create the game project

Note: Some of the steps in the next few sections are fairly basic and unrelated to the main subject of this chapter: Transitions. If you'd like to get to the meat of this chapter, feel free to skip ahead to the "Working with multiple scenes" section, where there's a starter project waiting for you.

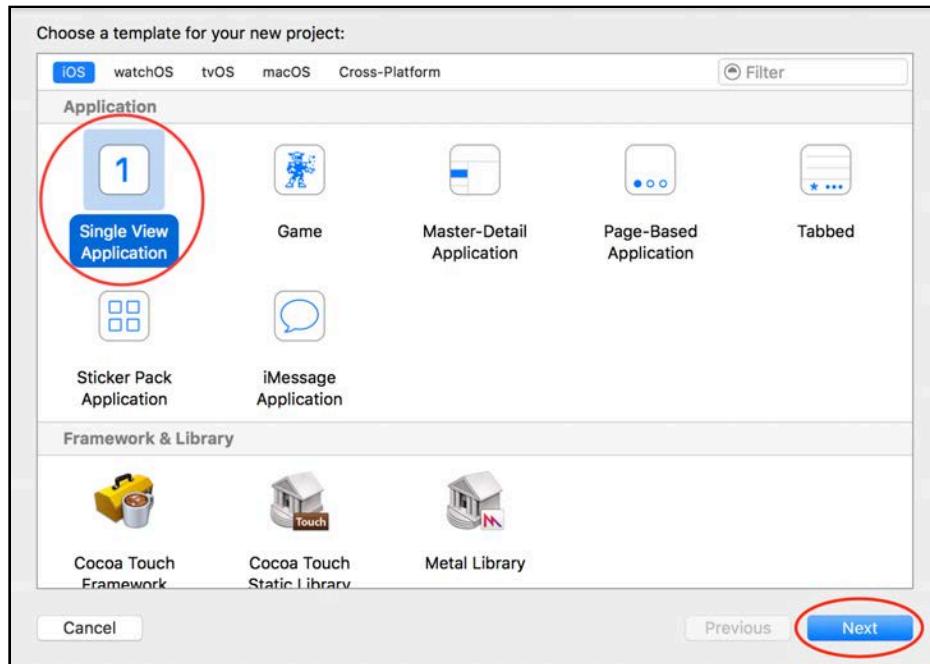
But if you'd like more practice setting up a project, keep reading!

It's template time! This time around you won't use the built-in Xcode Game template; you'll make use of the Single View Application template.

By now, you've made a game template the easy way, and you're well acquainted with the steps involved. But you're in the final section. It's time to level up and play around with advanced methods and options to incorporate SceneKit into existing applications.

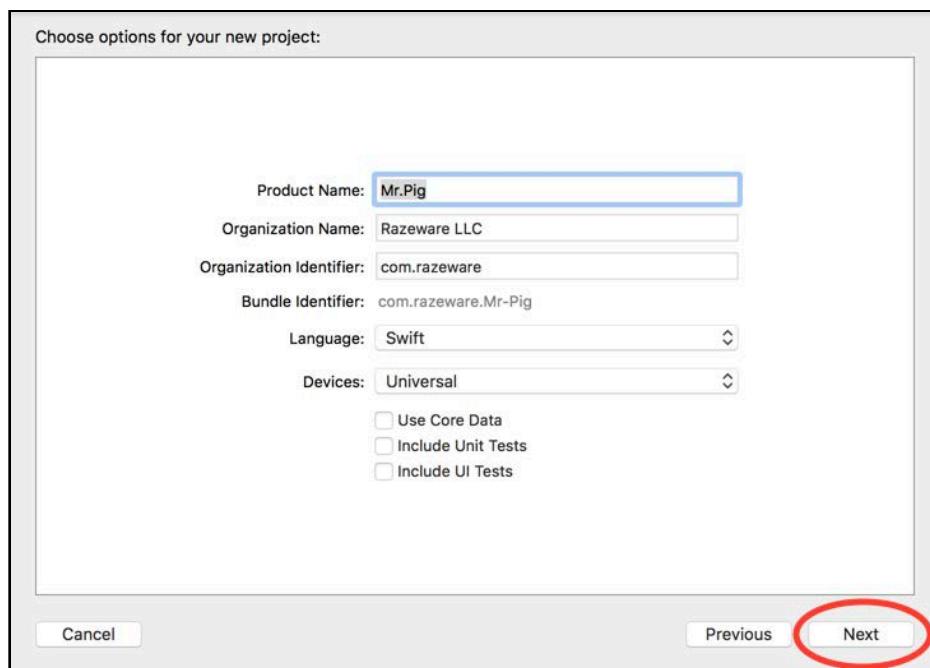
Create a Single View Application game project

Start Xcode and once started, press **Shift+Command+N** to create a new project. This'll launch the **Project Wizard**:



Choose **iOS > Application > Single View Application** template, and click **Next** to continue.

Here's where you set some basic options for your new project:



Make sure to set the following options:

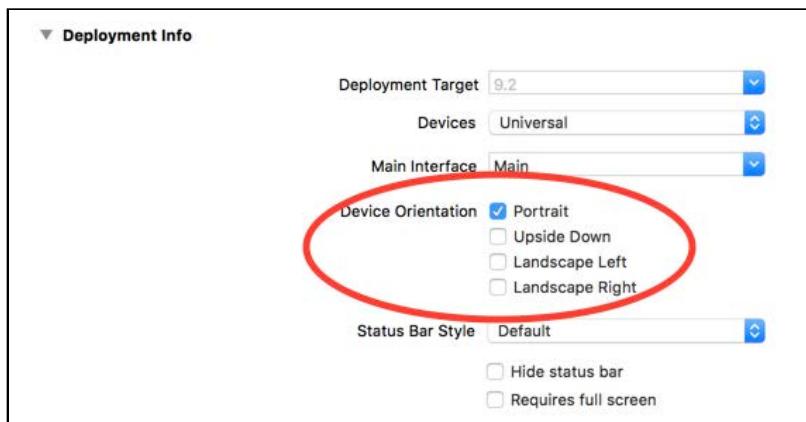
- **Product Name:** Name the application **Mr.Pig**.
- **Organization Name:** You can make this whatever you choose.

- **Organization Identifier:** This is your reverse domain identifier.
- **Language:** **Swift** should be your preference by now. :]
- **Devices:** Make this **Universal** so the application will run on an iPhone or iPad.

Leave the rest unchecked and click **Next**.

The final step is to choose a convenient location to save your project. Pick a directory and select **Create**; Xcode will work its magic and generate your project.

Finally, set the orientation to allow only **Portrait** under **Project Settings/General/Deployment Info**, like this:



So far so good! The setup is not all that different from a standard game project. You did it almost the same way except for choosing **Single View Application**.

Select **ViewController.swift** in the project navigator to continue.

```

import UIKit

class ViewController: UIViewController {

    override func viewDidLoad() {
        super.viewDidLoad()
        // Do any additional setup after loading the view, typically from a nib.
    }

    override func didReceiveMemoryWarning() {
        super.didReceiveMemoryWarning()
        // Dispose of any resources that can be recreated.
    }
}

```

So what's the big difference? Take a closer look:

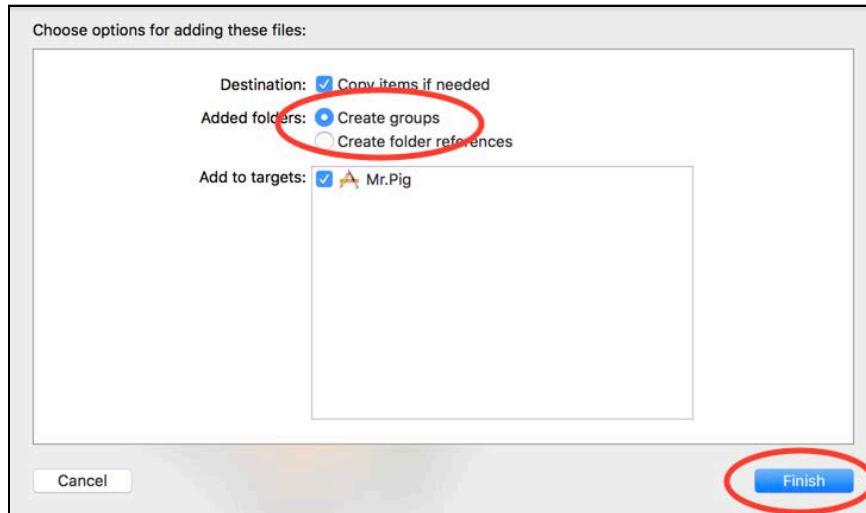
- **art.scnassets:** The first thing you might notice is that there is no **art.scnassets** folder. That's part of the game project template, so it wasn't created for you.
- **ViewController.swift:** This used to be **GameViewController.swift**, so the *Game* prefix fell away. The class still inherits from **UIViewController** same as before. In this section, you'll reference the **ViewController** class instead of **GameViewController**.

Note: You'll also notice that there's no boilerplate code to start the game. Fear not, you've been training for this.

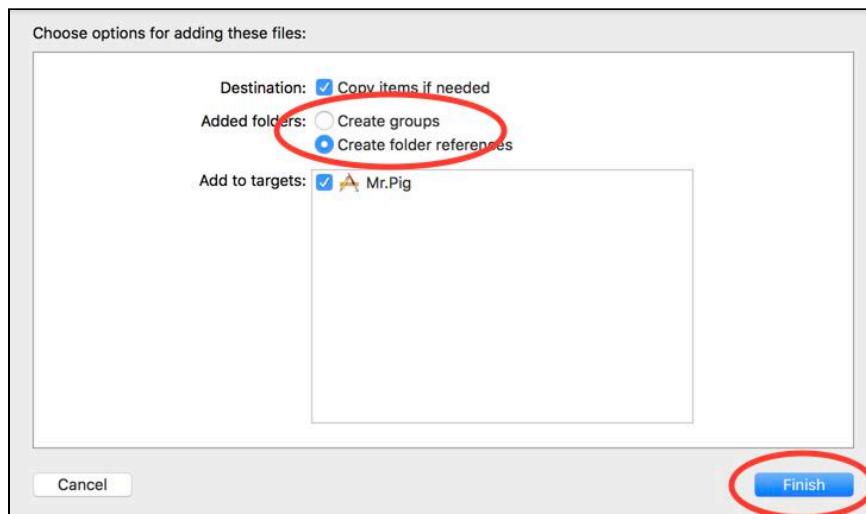
Adding resources to your project

There are a whole bunch of resources ready to go, and you just need to add them to your game.

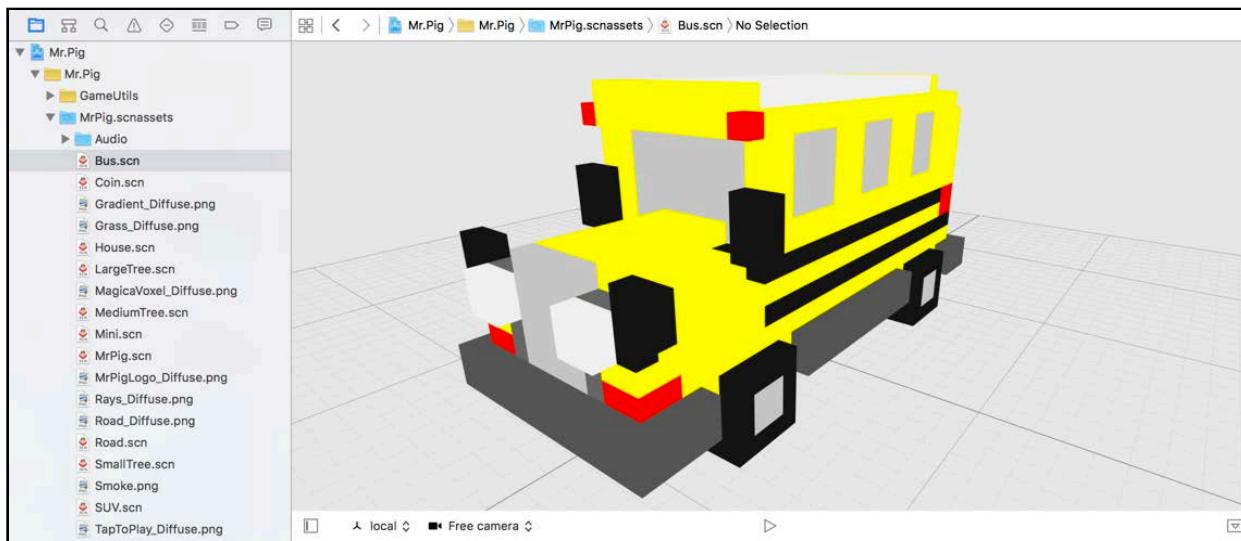
Start by dragging and dropping the **resources/GameUtils/** folder into your project. When prompted, make sure to add the folder as a **Group** and check the fields shown below:



Drag and drop the **resources/MrPig.scnassets** folder into the project next, this time choosing to **Create folder references** but no groups, like this:



Finally, open the **File Navigator** to take a closer look — if needed, reorganize the folders so they look like mine:



You'll find all sorts of hidden gems under these folders; here's a quick breakdown of what to expect:

- **GameUtils:** These are just a bunch of useful utilities you can use to make everyday tasks a little bit less taxing.
- **MrPig.scnassets:** This contains all the textures, 3D models, sound effects and even music to create Mr. Pig's world.

Note: Take some time to get yourself familiar with the content inside these folders. You'll be using it extensively in the coming chapters!

Setting up the app icon and launch screen

You'll find a **LaunchScreen** and **AppIcon** folder under the **resources** folder. These contain a bunch of app icons and a launch screen image for use in your project.

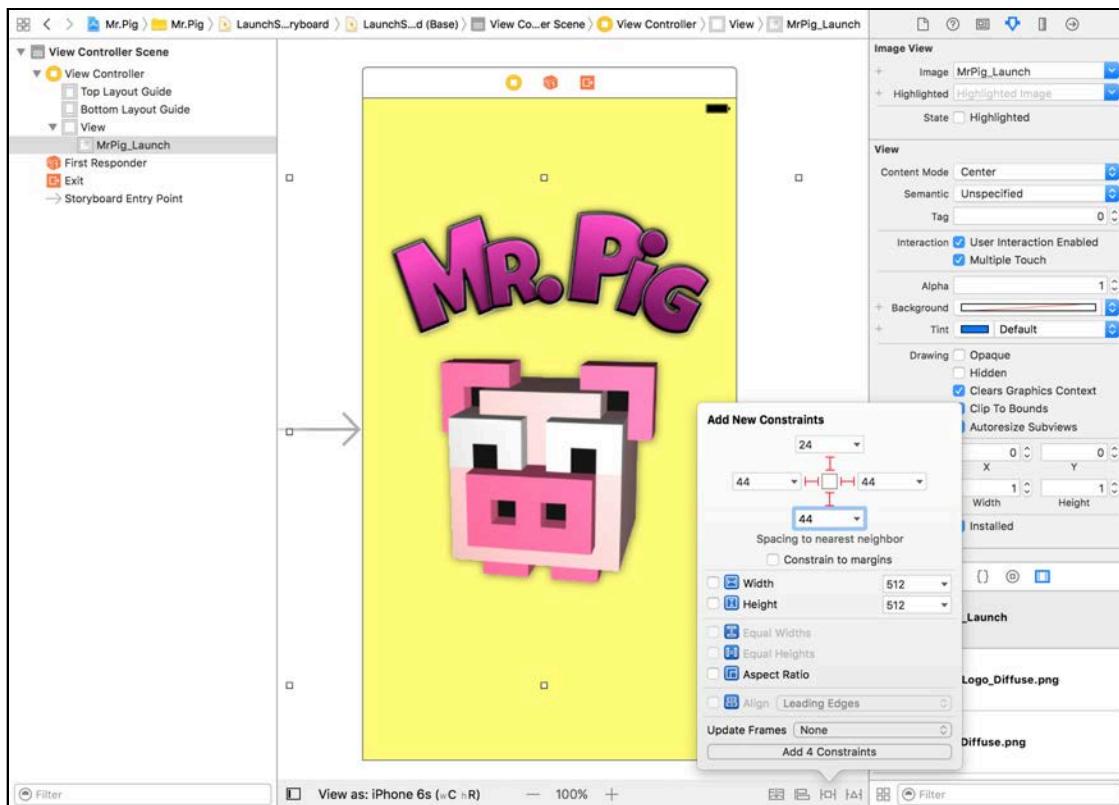
Drag and drop the appropriate app icons into the **Assets.xcassets** container.



Open the **LaunchScreen** folder. Drag and drop the **MrPig_Launch.png** into the **Assets.xcassets** folder. Now the image is available from your **Media Library**.



Now you can set up the launch screen with using the image.



Here are a few things you need to do right now:

- Drag and drop the launch image from the **Media Library**.
- Set the background color to a nice yellow.
- Remember to add some pin constraints; pinning the image view's edges to the container will do. Refer to the image above to see the pin constraints.
- Finally, make sure you set the **Content Mode** of the image view to **Aspect Fill** and uncheck **Clip to Bounds**.

Set up the SceneKit view

Now you need to set up the basic view controller, and then create the actual SceneKit view for your game.

Setting up the View Controller class

Under the project navigator, select **ViewController.swift**, then replace its contents with the following:

```
// 1
import UIKit
import SceneKit
import SpriteKit
// 2
class ViewController: UIViewController {
    // 3
    let game = GameHelper.sharedInstance

    override func viewDidLoad() {
        super.viewDidLoad()
        // 4
        setupScenes()
        setupNodes()
        setupActions()
        setupTraffic()
        setupGestures()
        setupSounds()
        // 5
        game.state = .tapToPlay
    }

    func setupScenes() {
    }

    func setupNodes() {
    }

    func setupActions() {
    }

    func setupTraffic() {
    }

    func setupGestures() {
    }

    func setupSounds() {
    }

    override func didReceiveMemoryWarning() {
        super.didReceiveMemoryWarning()
    }

    override var prefersStatusBarHidden : Bool { return true }
```

```
    override var shouldAutorotate : Bool { return false }
```

Take a quick look at what's happening here:

1. This part imports the usual suspects, but did you notice that you're now importing **SpriteKit** too? What's up with that? If you'll recall, this chapter deals with transitions, and SceneKit relies on SpriteKit functionality to make the transitions. So for now, just make a mental note of this incredibly important import.
2. The class is now known as the ViewController that simply inherits from the UIViewController.
3. This declares the game object that retrieves the shared instance of GameHelper. The helper contains some functionality that you'll use throughout the game.
4. The viewDidLoad() method is the first to execute when the application starts. Here you're simply calling a whole bunch of stubs that'll set up all the important aspects of your game later on.
5. Finally, you set the game to an initial state of tapToPlay.

Setting up the SceneKit view

Now to tackle the big hole you made for yourself by making use of a **Single View Application** template. You need to create an SCNView instance by manually creating the property that will hold your SCNView.

Add the following property to top of ViewController:

```
var scnView: SCNView!
```

This will hold the instance of the SCNView for quick access later on.

Add the following to setupScenes():

```
scnView = SCNView(frame: self.view.frame)
self.view.addSubview(scnView)
```

This creates an instance of SCNView by passing in the view.frame. The key part is where you add the SceneKit view as a subview of the current view with addSubview(_:).

Feel free to build and run if you'd like, but note you'll end up with a blank white screen because you still need to present a scene in the view.

Working with multiple scenes

Note: If you skipped ahead from earlier in this chapter, you can pick up at this point with the starter project in **/projects/starter/Mr.Pig**.

You can't have any fun with transitions between scenes until you set some up. The game will have two main scenes: a splash scene and a game scene.

Creating the game scene

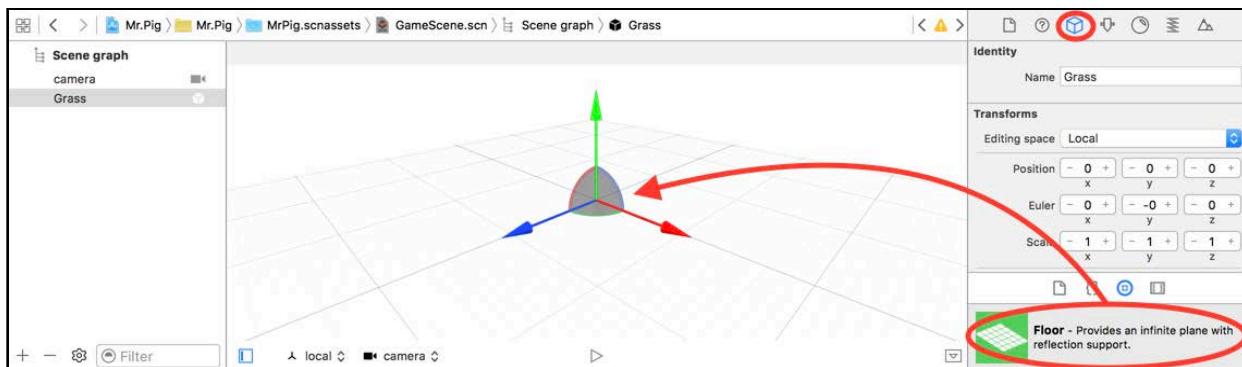
The game scene is where all the action takes place. You'll build the entire level inside the game scene.

To create a new scene, drag and drop a **SceneKit Scene File** from the **File Template library** into the root of your project.

Name the scene **GameScene.scn**, choose **MrPig scnassets** folder as destination and click **Create**.

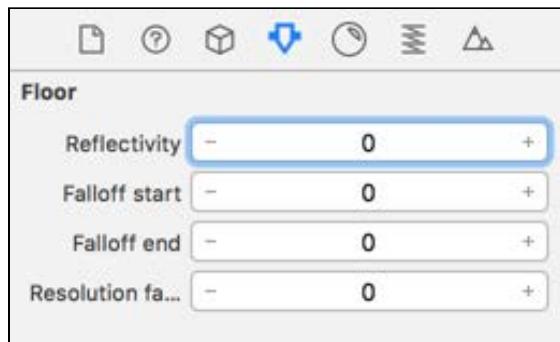


Make sure **MrPig scnassets/GameScene.scn** is still selected, then drag and drop a **Floor Node** into the scene from the **Object Library**. Select its **Node Inspector** to continue.



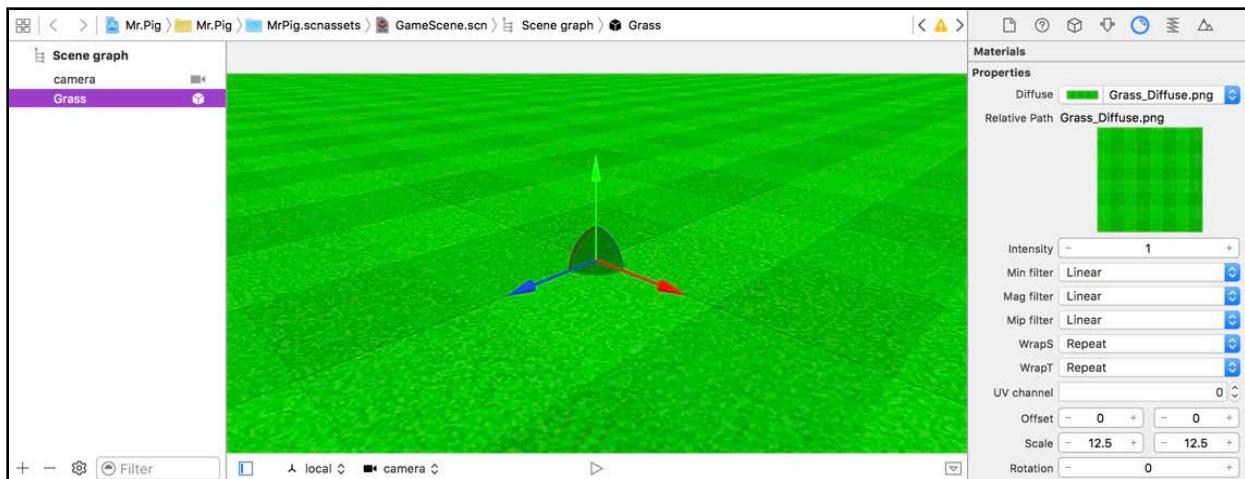
Name the node **Grass**, and zero out the **position** and Euler **rotation**.

Select the **Attributes Inspector**.



Set the **Floor Reflectivity** to 0 — you don't want the grass to be reflective because, well, grass isn't glass!

Move on to the **Materials Inspector**.



Select the **Grass_Diffuse.png** as the **Material Diffuse** map, then scale it down to 12.5 units vertically and 12.5 units horizontally. This action should repeat a the grass pattern across the floor node. It's so realistic you can almost smell freshly cut grass.

Create the splash scene

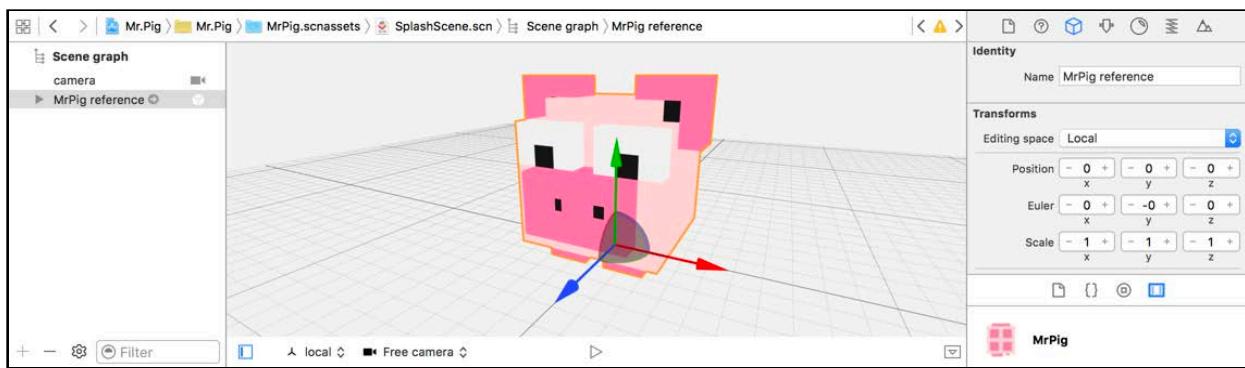
The splash scene will be the front scene where Mr. Pig will introduce himself with some serious dance moves. He's patient, energetic and will keep on rocking until your player initiates a game.

Drag and drop another **SceneKit Scene File** from the **File Template library** into the root of your project.

Name the scene **SplashScene.scn**, choose **MrPig scnassets** folder as the destination then click **Create**.



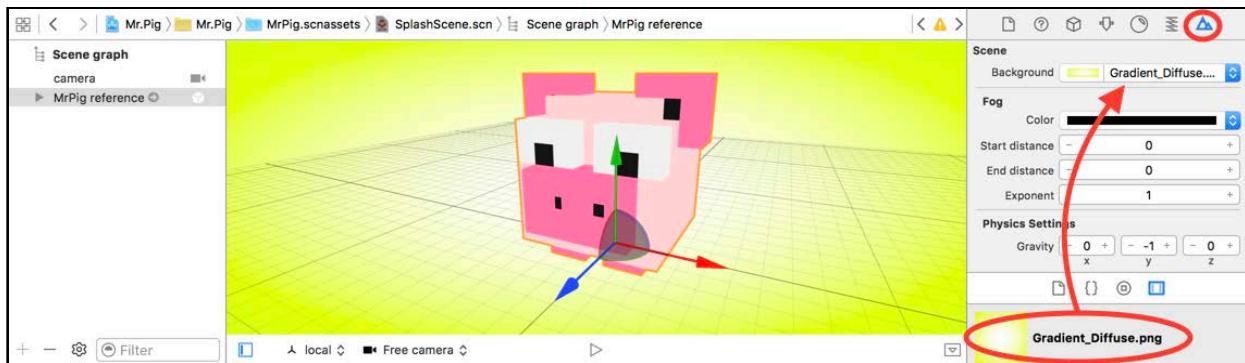
With **MrPig.scnassets/SplashScene.scn** still selected, drag and drop a **MrPig** reference node into the scene from the **Media Library**.



With the **MrPig** node still selected, go into the **Node Inspector** and zero out its position and rotation. Mr. Pig is in position now.

Next, you'll give the splash scene an aesthetically pleasing gradient background — solid colors are so 2002.

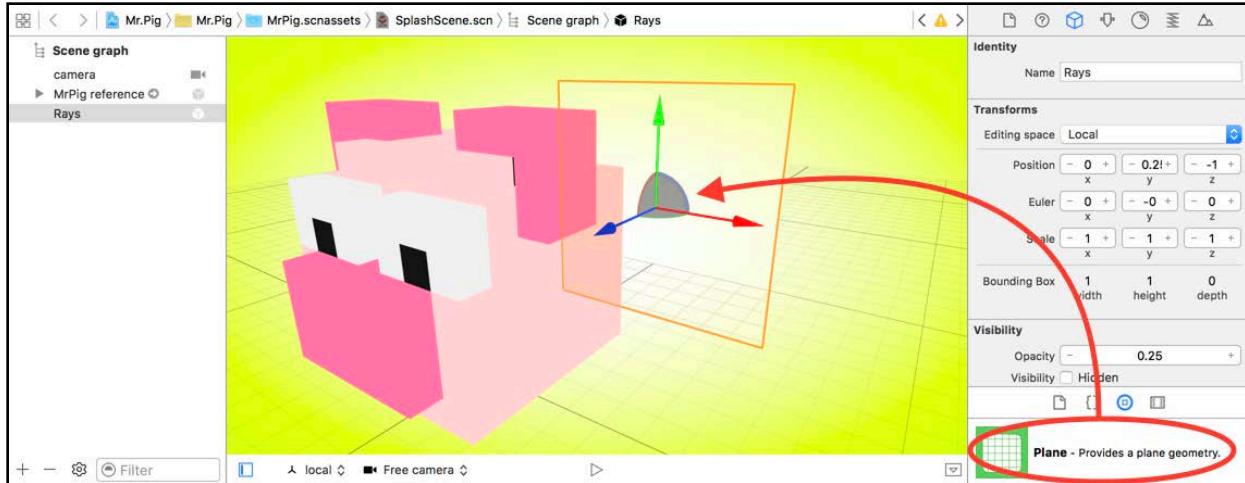
Make sure you still have the **MrPig** reference node selected then select the **Scene Inspector** — the very last inspector. Drag and drop the **Gradient_Diffuse.png** file from the **Media Library** into the **Scene Background** property.



The whole scene background should change to the gradient image. Yes, Mr. Pig loves bright colors. :]

Note: Since you're using a single square image for the background, SceneKit does something special by stretching it so that it fills the whole scene at all times. Just another cool way you can use some of the hidden features of SceneKit.

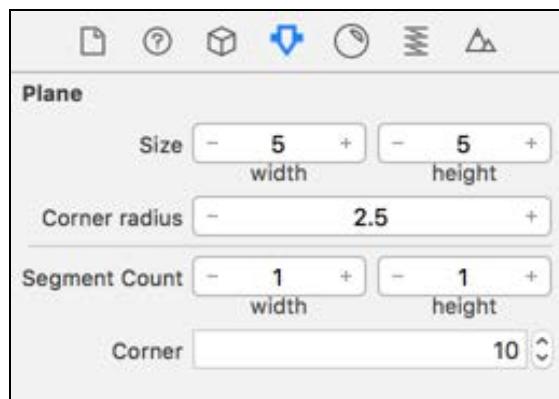
Now to create some sun rays behind Mr. Pig. Drag and drop a **Plane** node into the scene from the **Object Library**.



Name the node **Rays**, and set its position to (x:0, y:0.25, z:-1). Make sure it has a zero rotation. Also set **Visibility Opacity** to **0.25** to make the plane almost entirely transparent.

Now move on and adjust the plane dimensions under the **Attributes Inspector**.

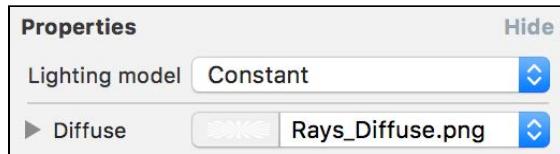
Set the **Size** to (x:5, y:5), and just for the fun of it, make the plane a disc by setting the **Corner Radius** to **2.5**, essentially half of its size.



Now you need to make the plane look like actual rays, and to do that you need to give it a nice little diffuse texture. Select the **Materials Inspector**.

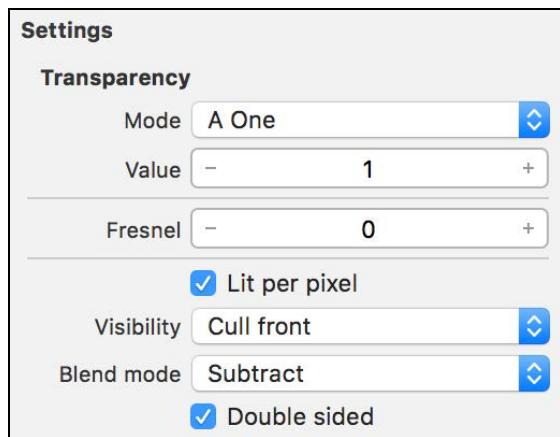
Select the **Rays_Diffuse.png** for a diffuse map. You should notice the plane changing into glorious rays, but you'll have a power struggle between the rays of light and your scene lighting on your hands.

To fix that, look right above the diffuse setting for **Lighting model** and set it to **Constant**.



Constant ensures that lighting will have no effect on the rays. Yes, you'll add those to the scene shortly.

Scroll down to the **Settings** section and set **Blend Mode** to **Subtract**, which will then darken the scene by using the blend diffuse map by means of subtraction.



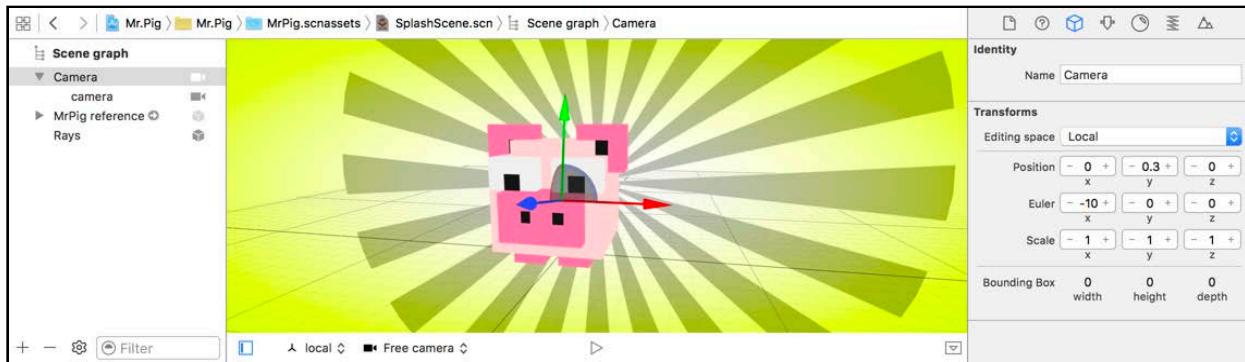
Setting up the camera and lights

What makes the eyes recognize dimension? Lighting, of course. And if you're adding lights then you need cameras. Lights, cameras, action!

By default, the splash scene already has a camera. You'll use it *mostly* as-is.

First, make sure nothing is selected under your **Scene Graph** tree then click the **+** button to add an **empty node** into the root.

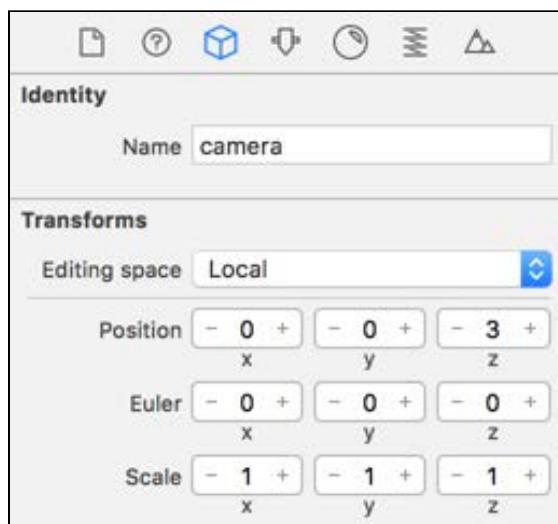
Name the empty node **Camera** and drag the original camera node under it, making it a child node. With the outer **Camera** node selected, use the **Node Inspector** to set its position to $(x:0, y:0.3, z:0)$ and its Euler angle to $(x:-10, y:0, z:0)$.



This will tilt the camera view downwards and aim it straight at the dancing swine almost as if he's holding a selfie stick.

Select the inner **camera** node so you can set some properties for it. You want to pull the camera back a bit on that selfie stick, but not too far, just enough to see Mr. Pig.

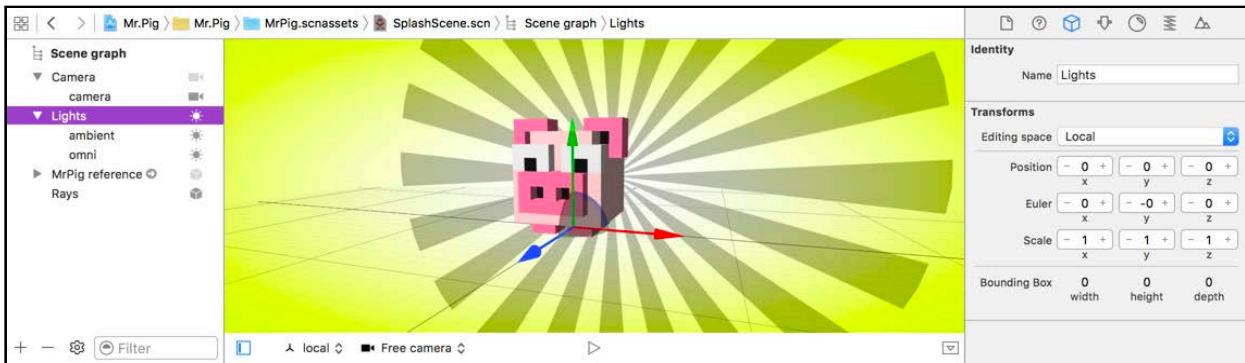
Set its position to $(x:0, y:0, z:3)$ and make sure its Euler rotation is $(x:0, y:0, z:0)$.



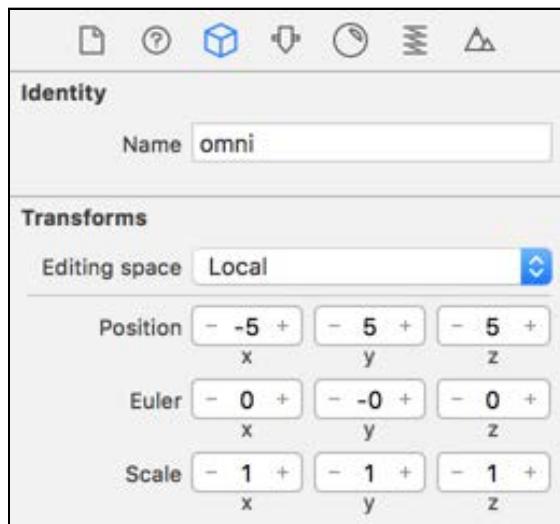
To ensure the camera is configured correctly, select the **camera** in the dropdown in the bottom-left of the scene editor to preview the view:



Now add another empty node into the root of the **Scene Graph**. Name it **Lights**. Drag and drop an **Ambient** and an **Omni** light into the scene from the **Object Library**.



Make sure you move them under the **Lights** node under the **Scene Graph**. You'll leave the attributes as-is, but you need to reposition the omni light. Select it then go to its **Node Inspector**. Position the light at $(x:5, y:5, z:5)$.



Mr. Pig is looking rather dapper! :]

Challenge

You're almost done with the entire splash scene, but there are two more components to add: the logo and tap-to-play nodes. But you're more than capable of handling these two tasks on your own. :]

Your mini challenge is to produce the same results as shown below. Take special note of the **Scene Graph** structure with the added **Logo** and **TapToPlay** nodes that are representing the precious pink Mr. Pig logo and Tap To Play caption at the bottom of the scene.



The two nodes are plane nodes with simple diffuse maps on them. Here are a few tips if you need a helping hand:

- **The Logo node:** It uses a basic **Plane** node with the **MrPigLogo_Diffuse.png** applied, set to a **size of width:1, height:0.5**. Make sure to **position** it in front of and above our hero at (x:0, y:1, z:0.5).

Also make sure it's not affected by any light, just like you did with the **Rays**.

- **The TapToPlay node:** Also uses a basic **Plane** node with the **TapToPlay_Diffuse.png** applied, set the **size** to **width:1, height:0.25**. Position it in front of and below the pig at (**x:0, y:-0.3, z:0.5**). It should also be unaffected by any light.

Note: You can find the solution to this mini challenge under the **/projects/challenge/Mr.Pig** folder.

Loading and presenting the splash scene

Finally, you've got your splash scene set up, and the game scene is on its way. You're at the point to where you'll load them up and present the splash scene.

You need objects to hold your scenes, so add the following properties to **ViewController**:

```
var gameScene: SCNScene!
var splashScene: SCNScene!
```

Add the following code to **setupScenes()**:

```
// 1
gameScene = SCNScene(named: "/MrPig.scnassets/GameScene scn")
splashScene = SCNScene(named: "/MrPig.scnassets/SplashScene scn")
// 2
scnView.scene = splashScene
```

Take a closer look:

1. This loads both **GameScene scn** and **SplashScene scn** to their respective properties from the **MrPig scnassets** folder.
2. This part sets the splash scene as the initial scene for your game. Once everything loads and the game starts, you'll see the splash scene first.

Do a quick build and run just to make sure all is well.



You're all good if your game started up and showed the splash scene. Oh, yeah!

How do you get from the splash scene to the game scene? Well, if you just muttered that question to yourself then hurry to the next part. It'll show you exactly how.

Transitions

Finally you're ready to play around with **transitions**.

Wait, what exactly are transitions? One way to learn is to go watch all seven episodes of "Star Wars" again. See you back here in about 14 hours.

George Lucas, in all his brilliance, mastered the art of using **wipes** to transition between scenes. One could even go so far as to say that without these classic sweeping effects, the movies would be less magical.

There are many more kinds of transitions, such as dissolves, cross fades and cuts.

SceneKit leverages SpriteKit's `SKTransition` object for transition effects, and that's *precisely* why you imported SpriteKit. If you're familiar with SpriteKit, you should feel right at home tinkering with these effects.

The `SKTransition` object will help you animate your move from the active scene to the next scene by using various transitioning effects.

There are quite a few out-of-the-box transition effects at your disposal:

- **crossFade(withDuration:)**: Cross fades from current scene into the new scene.
- **doorsCloseHorizontal(withDuration:)**: Presents the new scene as a pair of closing horizontal doors.
- **doorsCloseVertical(withDuration:)**: Presents the new scene as a pair of closing vertical doors.
- **doorsOpenHorizontal(withDuration:)**: Presents the new scene as a pair of opening horizontal doors.
- **doorsOpenVertical(withDuration:)**: Presents the new scene as a pair of opening vertical doors.
- **doorway(withDuration:)**: The current scene disappears as two doors open to present the new scene as though it was behind the doors.
- **fade(withColor:)**: The current scene first fades into a constant color then presents the new scene by fading into it.
- **fade(withDuration:)**: The current scene first fades to black then presents the new scene by fading into it.
- **flipHorizontal(withDuration:)**: Presents the new scene by flipping the current scene away horizontally.
- **flipVertical(withDuration:)**: Presents the new scene by flipping the current scene away vertically.
- **moveIn(withDuration:)**: Presents the new scene by moving it on top of the current scene.
- **push(withDuration:)**: Presents the new scene by pushing the current scene out of view.
- **reveal(withDuration:)**: The current scene moves out to reveal the new scene underneath it.
- **transition(withDuration:CIFilter:)**: Presents the new scene by making use of Core Image Filters for the transition effect.

Adding a transition effect

In this part, you're going to kill two birds with one stone.



Relax, that's just an old expression; you're not really going to kill any birds! :]



You're about to add basic functions that will control the three game states, i.e., **playing**, **tapToPlay** and **gameOver**. Your game will go through. Along with that, you'll add some code to handle the actual transition from one scene to another.

The first method you're about to add will switch your game into the **playing** state. It'll also transition into the game scene.

Add the following function to `ViewController` class:

```
func startGame() {
    // 1
    splashScene.paused = true
    // 2
    let transition = SKTransition.doorOpenVertical(withDuration: 1.0)
    // 3
    scnView.present(gameScene, with: transition, incomingPointOfView: nil,
    completionHandler: {
        // 4
        self.game.state = .playing
        self.setupSounds()
        self.gameScene.paused = false
    })
}
```

```
    })  
}
```

Take a look at what's happening here:

1. You're assuming the game can only start from the splash scene. So the first thing you're doing here is manually pausing the splash scene by setting the `paused` property to true. This will stop all actions and any active physics simulations in the splash screen.
2. Here's how you create a transition effect using the `SKTransition` object. This part simply presents the new scene while the current scene slides away like two vertical doors opening up over a 1 second period.
3. You then make a call to `SCNView`'s `present(_:with:incomingPointOfView:completionHandler:)` method by passing in the freshly created transition effect. You can also specify which point of view to use for the transition, but because all your scenes will only have one camera you leave this `nil`. Then you kick in a completion handler when the transition effect completes.
4. This bit executes after the transition completes and officially sets the game state to **playing**. It also loads up the correct sounds for the scene and unpauses the scene.

The following method switches the game into a **gameOver** state. This typically happens when Mr. Pig gets hit by one of the evil gas-guzzling vehicles.

Add this to `ViewController`:

```
func stopGame() {  
    game.state = .gameOver  
    game.reset()  
}
```

This code simply makes sure the game state is set to **gameOver**, and it also resets the scores in preparation for the next game.

The last method switches the game into **tapToPlay** state. This is where the splash scene is presented to the player, and the game waits for input.

Add the following method to `ViewController`:

```
func startSplash() {  
    // 1  
    gameScene.paused = true  
    // 2  
    let transition = SKTransition.doorOpenVertical(withDuration: 1.0)  
    scnView.present(splashScene, with: transition, incomingPointOfView:  
        nil, completionHandler: {  
            self.game.state = .tapToPlay  
            self.setupSounds()  
        })  
}
```

```
        self.splashScene.paused = false
    })
```

Now for a closer look at what's happening here:

1. This simply pauses the game scene, essentially preventing all physics simulations and actions from running.
2. This creates a transition effect then performs the actual transition to the splash scene. Once the transition completes, the game state is officially set to **tapToPlay**, the splash scene sounds are reconfigured, and the splash scene is unpause.

Now you have all the basic methods to control the flow of your game setup.

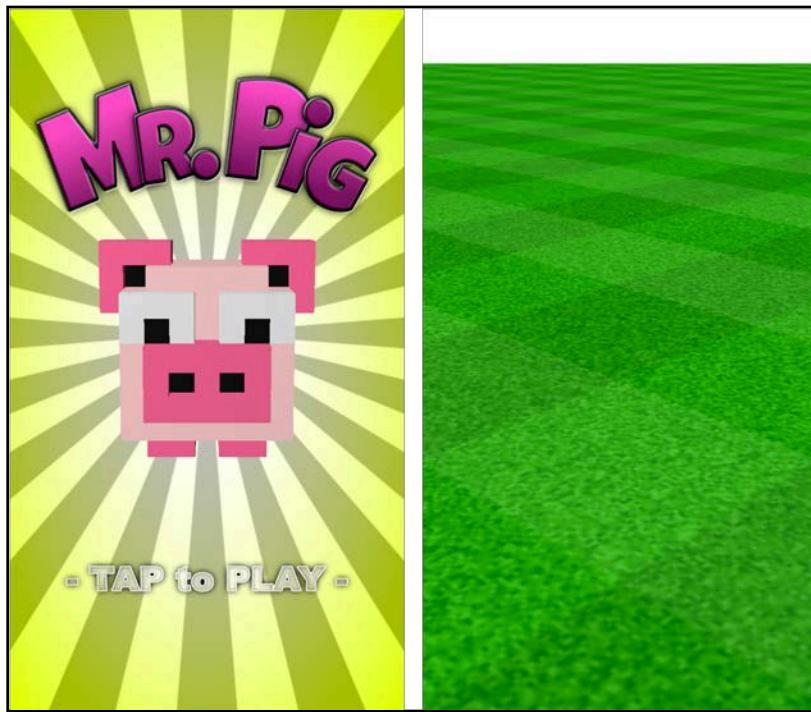
There's still one little method left to add: the one that kicks off your game once the user taps to play.

Add the following method to ViewController:

```
override func touchesBegan(_ touches: Set<UITouch>, with event: UIEvent?) {
    if game.state == .tapToPlay {
        startGame()
    }
}
```

The touchesBegan(_:) event will fire whenever the player taps on the screen. You're only interested in tap events while in a **tapToPlay** state. Once the event fires, you know the player wants to play the game, so you trigger startGame().

Time for a build and run to test that transition.



Note: Be sure to test this on a device, not the simulator, as the simulator may be too slow to show the transition in full splendor.

The game starts up with the splash scene and when you tap to play, the scene transitions into the game scene. Perfect!

Where to go from here?

As usual, you can find the final project for this chapter under the **/projects/final/Mr.Pig** folder.

You just earned yourself a gold star for completing the first chapter in this section, and your game is already looking mighty fine. :]

Here are some key takeaways from this chapter:

- **Single View Application:** You've now learned how to add SceneKit to nearly any type of app. No longer must you rely on the Game Template.
- **Transitions:** You've learned that SceneKit relies on SpriteKit for transitions, and you added a basic transition effect to your game.

Take a quick break, but hurry back because things will get more interesting in the next chapter. You'll start building the game scene!!

20

Chapter 20: Advanced Scene Creation

Chris Language

Getting started

Your game is off to a great start. In the previous chapter, your main focus was creating the basic project for your game. Not only that, but you also created the two main scenes for your game — the splash screen and the actual game. The rest of your focus was on making the splash scene pop and setting up a basic transition to the game scene.

In this chapter, your focus will shift towards building out the game scene.

You've already created a massive grass plane that forms the basis of the lovely park in which Mr. Pig lives and collects coins.

In this chapter, you'll fill in some missing details: those two nasty, traffic-clogged highways, tranquil trees, and the star of the game.

Note: This chapter continues where the previous one left off, so if you followed along you can keep using the same project. Otherwise, you can load up the starter project for this chapter from **projects/starter/Mr.Pig/**.

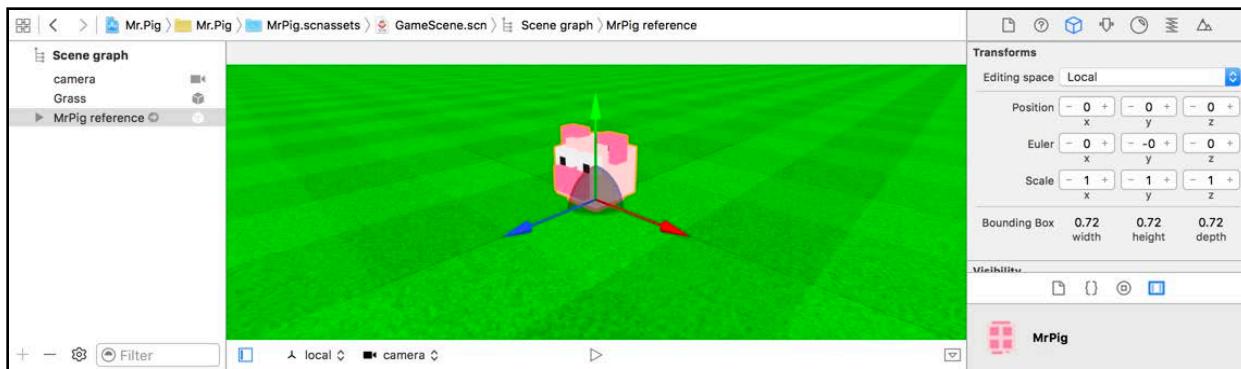
Add the hero

You'll start off by adding our hero, Mr. Pig, to your game scene. He'll make a good reference point when you're placing the rest of the objects.

Introducing Mr. Pig

With your project navigator open, navigate down and select **MrPig.scnassets/ GameScene scn**.

Drag and drop a **MrPig** reference node from the Media Library into the scene.



Make sure you zero out his **position** and **rotation** — sweet, that was almost too easy.

Quickly jump over to **ViewController.swift** and add the following property to ViewController:

```
var pigNode: SCNNode!
```

This property will hold the instance of Mr. Pig in the game scene. Later on, if you wanted Mr. Pig to jump, you'd run an action on this node.

Add the following line of code to `setupNodes()`:

```
pigNode = gameScene.rootNode.childNode(withName: "MrPig", recursively: true)!
```

This method is called after **GameScene scn** loads, so this line of code is safe to use as a means of binding `pigNode` to the actual object in your game scene.

Note: Although **MrPig** is a reference node, you still access the node in the game scene as if it were a non-reference node.

Set up camera and lights

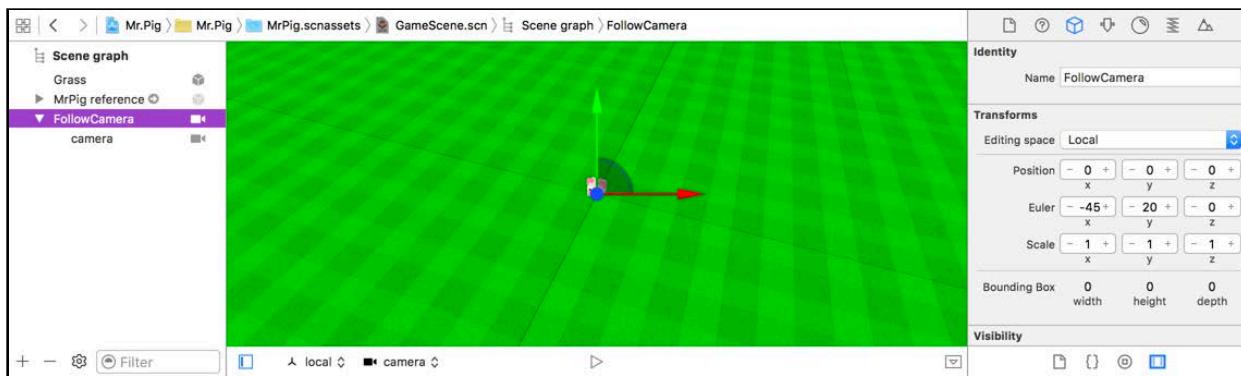
Now that you have something more than just a massive grass field to look at, it's time to set up a camera and some lights.

Again, you'll make use of the "selfie stick" principle by creating an empty node to act as the focus point for the camera or light — this approach simplifies and eliminates a whole bunch of mathematical issues you can't possibly mind skipping. :]

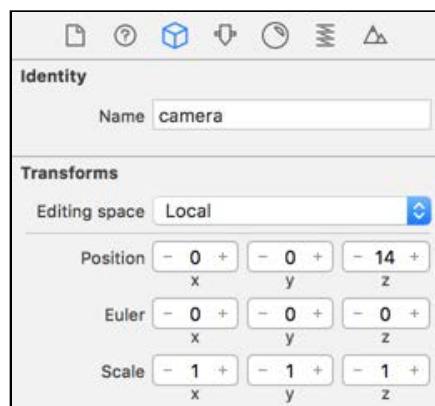
Creating the follow camera node

Go back to **MrPig.scnassets/GameScene scn** to set up the camera.

First, make sure nothing is selected under your scene graph, then click the **+** button to add an empty node into the scene graph. Select the node and rename it **FollowCamera** under the Node Inspector, zero out its **position** and set **Euler** to $(x:-45, y:20, z:0)$ to adjust the rotation.



Next, drag and drop the existing **camera** node under the newly added **FollowCamera** node. With **camera** still selected, change its position to $(x:0, y:0, z:14)$ and zero out **rotation**.



Select **camera** to be your view point at the bottom of the Scene Editor. Your scene should now resemble the image above.

At this point, you're almost done playing around with the camera, but you still need to add some code for it. Select **ViewController.swift** and add the following properties to ViewController:

```
var cameraNode: SCNNode!
var cameraFollowNode: SCNNode!
```

These will hold instances of **camera** and **FollowCamera** in code.

Add the following to `setupNodes()`:

```
// 1
cameraNode = gameScene.rootNode.childNode(withName: "camera",
recursively: true)!
cameraNode.addChildNode(game hudNode)
// 2
cameraFollowNode = gameScene.rootNode.childNode(withName: "FollowCamera",
recursively: true)!
```

What's going on in there?

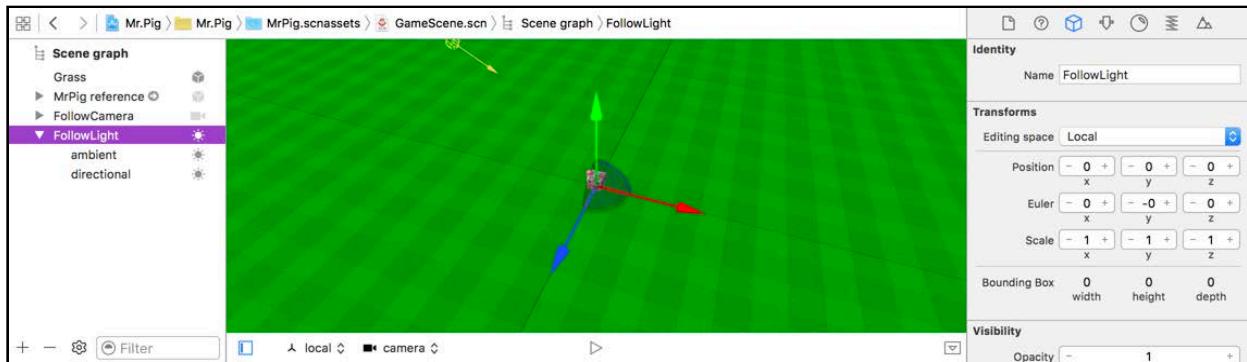
1. This binds `cameraNode` to **camera** in the game scene. Then, you add `hudNode` as a child node to keep the HUD in view of the camera at all times. You use the game helper to create `hudNode`, and in turn, it'll help to display information to the player.
2. This binds `cameraFollowNode` to **FollowCamera** so that when you want the camera to follow the pig around the scene, all you'll need to do is update the position for `cameraFollowNode` so it's the same position as the pig.

Creating the follow light node

You'll follow a similar process to create the lights for your game scene as you did to set up the camera.

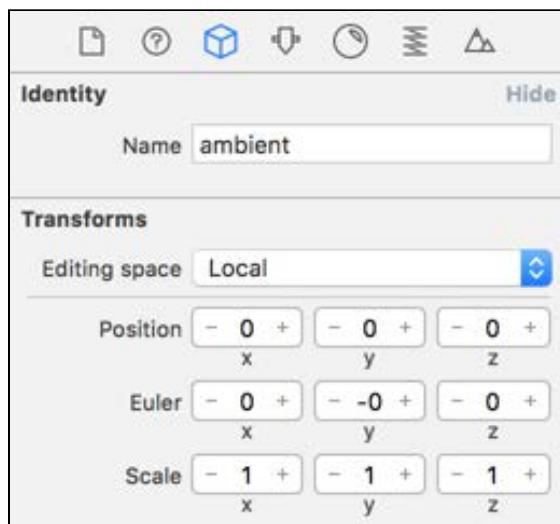
This scene will make use of two basic lights: an ambient light for fill and a directional light to mimic sunlight and the hard shadows it casts.

First, make sure nothing is selected under your game scene graph. Then click the **+** button to add an empty node. Name it **FollowLight** and zero out both the **position** and **rotation**.

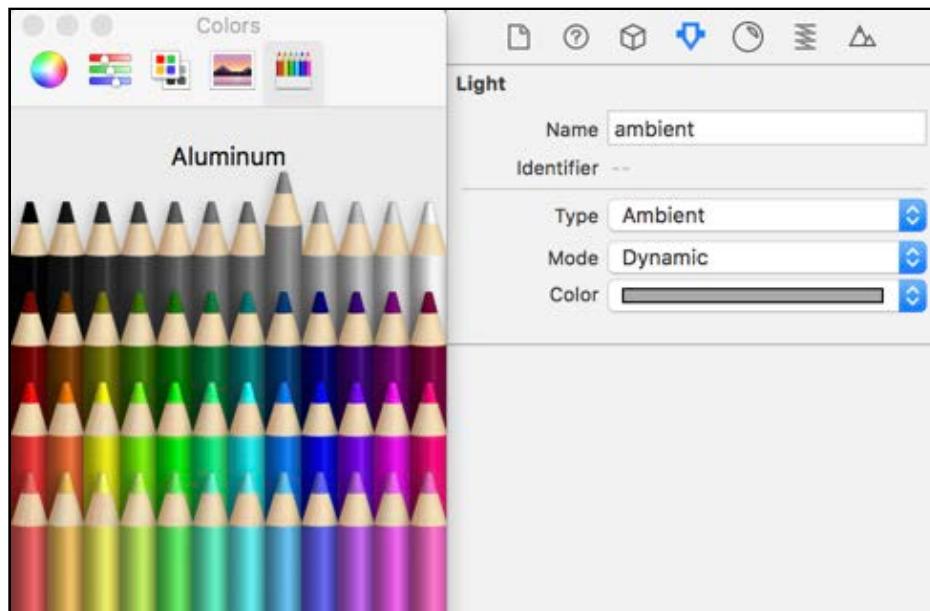


Drag and drop an **Ambient light** and a **Directional light** into the game scene from the Object Library. Make sure both are children of **FollowLight**.

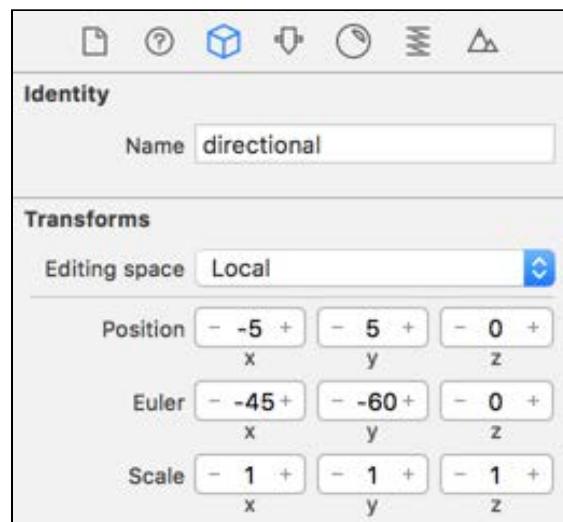
Select the **ambient** light, and zero out its **position** and **rotation** in the Node Inspector.



Then, move on to the Attributes Inspector and give the ambient light a mid-grey color: click the colored bar next to **Color** to bring up the color picker. Go to the crayons tab and pick **Aluminum** — this will brighten up the scene a little more.

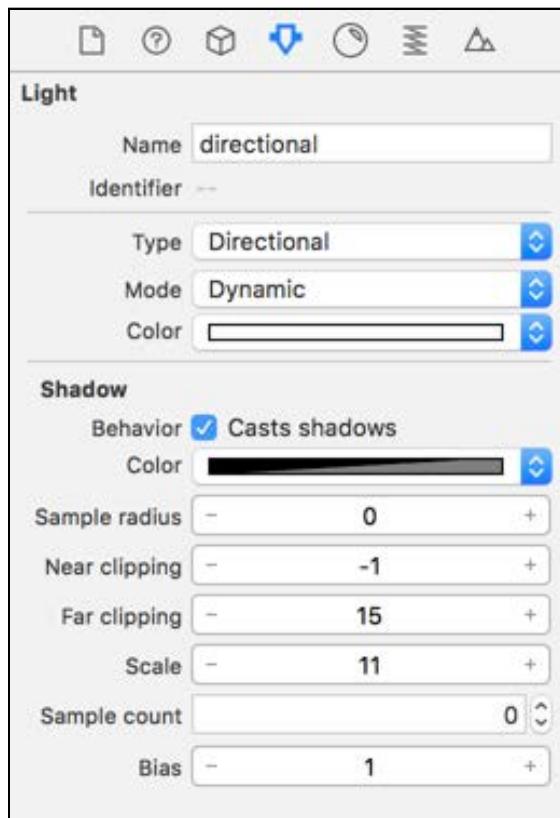


Now select the **directional** light and bring up its **Node Inspector**. Set the **Position** to (x:-5, y:5, z:5), and adjust the rotation by setting **Euler** to (x:-45, y:-60, z:0).



This places the directional light above and to the left of the scene, lighting up everything nicely.

Move on to the Attribute Inspector to configure **Light** and **Shadow** properties.



This next list will both tell you what to change and give you some detail about the properties:

- **Behavior:** Check this to make the light cast shadows.
- **Sample radius:** Set this to **0** so there's no blurring on the edges of shadows cast by this light. For this game, which is set outdoors, the directional light should mimic the sun and the crisp shadows it casts.
- **Near/Far clipping:** Specify a value of **-1** for **Near clipping** and **15** for **Far clipping**. Only surfaces between the range of the near and far clippings can have shadows cast upon them. Limiting this range is important for performance, and you calculate how large it will be based on the light source's position.
- **Scale:** Set this to **11**. This sets the extent of the orthographic projection for the directional light. This setting is large enough to cast shadows that fill the entire view.
- **Sample count:** Set this to **0**. Again, you want the light to cast a hard shadow. A higher sample count produces softer shadows, so you want to set it as low as possible.

Once you configure both lights, you should end up with the following result.



Wait a minute, why on earth should a light follow the pig around the scene anyway? Is he a diva that demands the spotlight? Not really — it's all about performance!

You've already limited the directional light's shadow via clipping, but that's based on the light's position. When you pan around the scene, you'll find areas that fall outside of the clipping range. Those parts will look very strange without shadows.

To overcome this issue, you simply set the light to follow the camera view, allowing the shadow clipping region to align with the camera. In short, this approach constrains the task of casting shadows to objects that are within the camera's *current* point of view.

The alternative is rather expensive and would slow the game — all in the name of producing shadows the user can't even see.

That's why you want the light to follow the pig around the scene.

The only bit left now is to write some code. Start by adding the following property to `ViewController`:

```
var lightFollowNode: SCNNode!
```

This will hold the instance of **FollowLight**.

Add the following code to `setupNodes()`:

```
lightFollowNode = gameScene.rootNode.childNode(withName: "FollowLight",  
recursively: true)!
```

This binds `lightFollowNode` to **FollowLight**. Now you can move this node to the same position as **FollowCamera** to make sure that the objects in view always cast pretty shadows for the player to see.

Do a quick build and run to review what you've done so far.



The game should start up and show the splash scene. Start a game and watch as the scene transitions to the game scene, revealing a lonesome little pig standing on massive, open grass plane.

Notice the effect of the hard shadow cast by the “sun”. It looks hot on that grass. You can almost smell sizzling bacon! :]

Add highways and traffic

Now to do the bidding of that big, bad wolf who built the mall down the street. It seems that his deal included an easement for a new highway straight through Mr. Pig’s lovely green park.

Unfortunately, traffic is extremely dangerous for little park-strolling pigs.

Put on your hard hat; it’s time to build some highways and a nice big traffic jam while you’re at it!

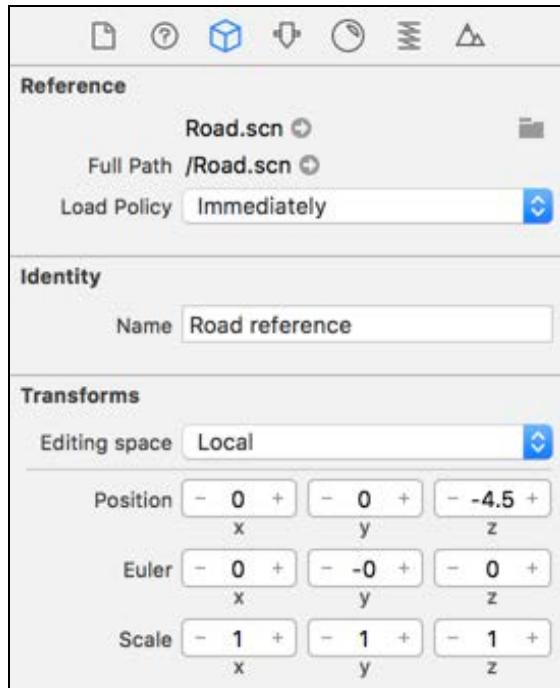
Adding the highways

First, make sure nothing is selected in your scene graph, then click the **+** button to add an empty node into the scene. Name it **Highway**.

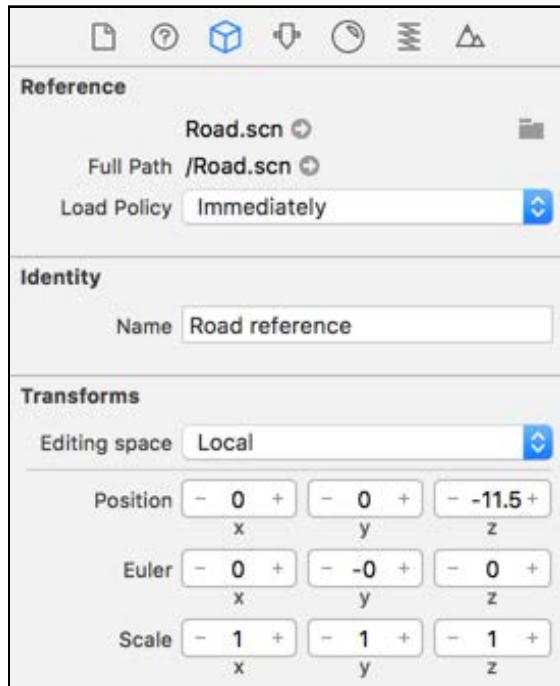
You’ll use this as a container node for the two highways.

Next, drag and drop two **Road** reference nodes from the Media Library into the scene, and make sure to place both of them under **Highway** node.

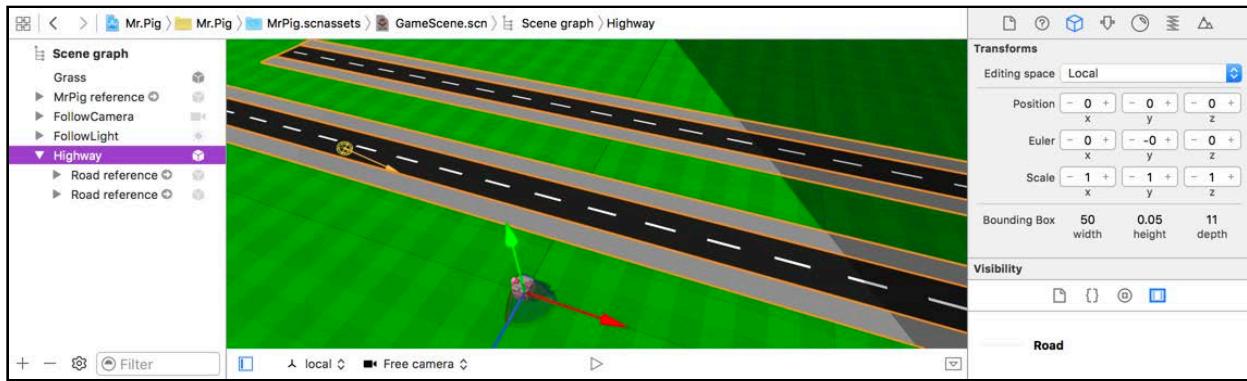
Select the first road, **position** it at (x:0, y:0, z:-4.5) and **zero** out the **rotation**.



Now select the second road and **position** it at (x:0, y:0, z:-11.5) to set it slightly away from the first one. Make sure to **zero** out the **rotation** for this road.



Once you're done positioning both the roads, select **camera** as your point of view in the Scene Editor. You should see something like this:

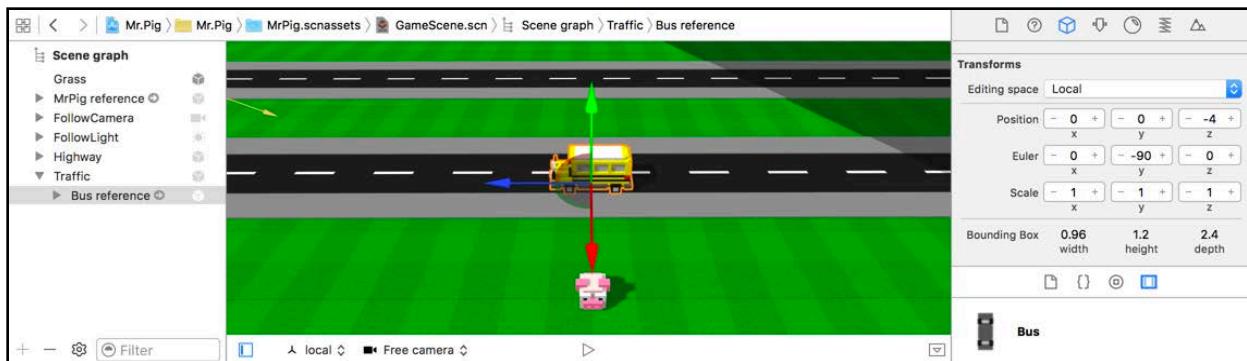


Adding the traffic

Build it and they will come, they say. Sure enough, you've built the road and are about to make the traffic come. :]

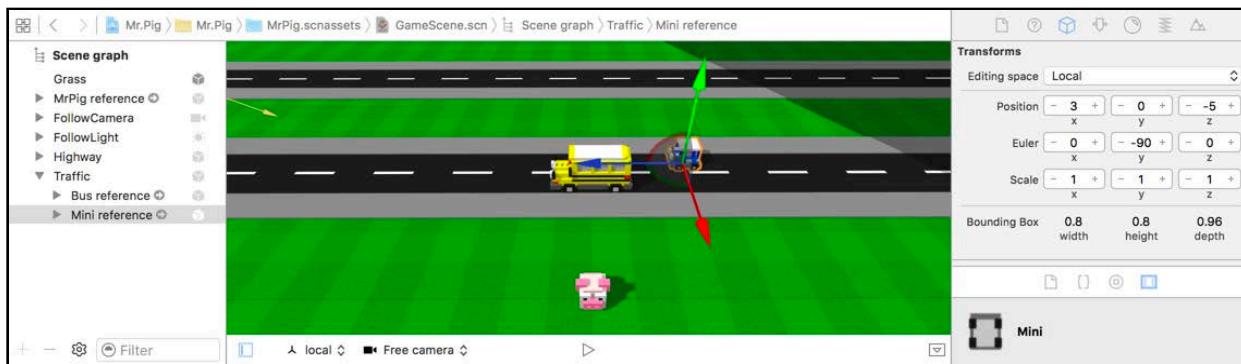
Once again, make sure nothing is selected in your scene graph. Add another empty node to serve as the container node for all the traffic in your game scene. This time around, name it **Traffic**.

Now drag and drop a **Bus** reference node into your scene from the Media Library. Make sure you move the **Bus** node under the **Traffic** node, and then set its **position** to (x:0, y:0, z:-4) and **rotation** to (x:0, y:-90, z:0).

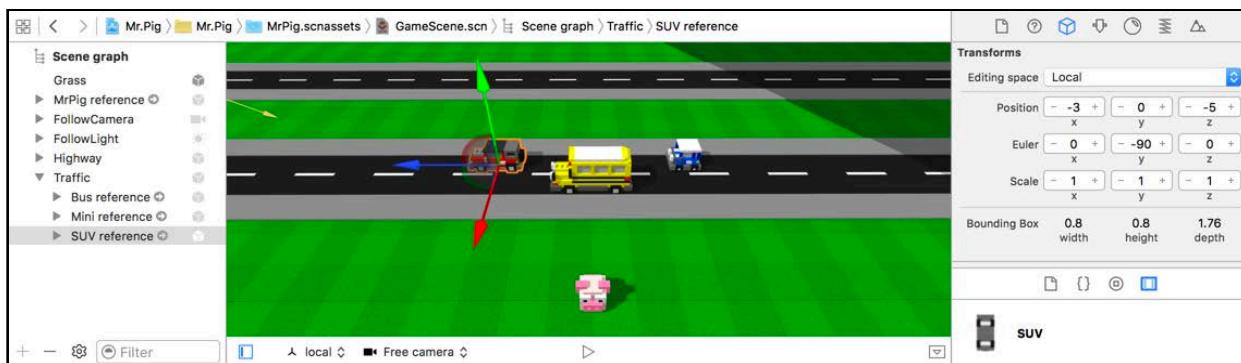


This places the bus neatly on the left lane of the first highway, facing left. Great!

Drag and drop a **Mini** reference node from the Media Library into the scene, and make sure to place it under the **Traffic** node as well. This time, place the Mini in the right lane and set **position** to (x:3, y:0, z:-5). **Rotate** it to (x:0, y:-90, z:0) so that it also faces left, like so:



Now drag and drop an **SUV** reference node from the Media Library, and also place it under the **Traffic** node. Place the SUV in the right lane as well – slightly ahead of the Mini – at position (x:-3, y:0, z:-5) and rotate it to (x:0, y:-90, z:0).



Great job! Now for the coding bit. Select **ViewController.swift** and add the following property to ViewController:

```
var trafficNode: SCNNNode!
```

This time, instead of making a property for each reference node in traffic, you'll simply use one container node to hold all the vehicles.

Add the following to `setupNodes()` :

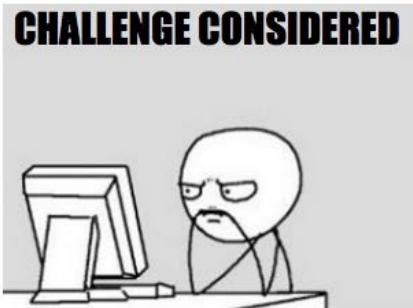
```
trafficNode = gameScene.rootNode.childNode(withName: "Traffic",
recursively: true)!
```

This binds `trafficNode` to the **Traffic** node in the scene. Now you can easily access all the children of this node to make the traffic move.

Challenge

Time for a little fun with traffic. When's the last time you got to make a traffic jam happen just for kicks?

Now that the first few vehicles are in place, you should know what's coming next. Your challenge is to fill up those highways with even more traffic — lots more.



The final result should look something like this:



Here are some guidelines to follow while adding more traffic:

- Make the left lane a bus lane. Keep the right lane for the smaller, faster vehicles.
- Make one highway's vehicles drive left and the other's drive right.
- To make your life easier, use the **Option** key to make quick copies of something already placed in the scene.
- Also make sure to hold the **Command** key when positioning the cars so they snap to nice round numbers.
- Remember to leave enough space between vehicles for a little pig to run through; nobody wants to play an impossible game!
- Once you've finished one highway, select all its vehicles and drag them to the other highway while holding **Option** to make a copy. Then, simply rotate them 180 degrees so that they face the other direction.
- Again, while you rotate the vehicles, hold the **Command** key so that the angles snap into place.

CHALLENGE ACCEPTED



Once you're done adding all the traffic, do another build and run for a quick sanity check.



Your poor little pig is lonely no more! He now shares the once lovely park with two nasty congested highways. :]

Note: If you struggled a bit or want to push ahead, you'll find the completed project after this challenge under **projects/challenge/Mr.Pig/**.

Add trees

At the moment there's one critical element still missing — those cute little trees! It looks like someone built a massive highway across a soccer field, not a green park.

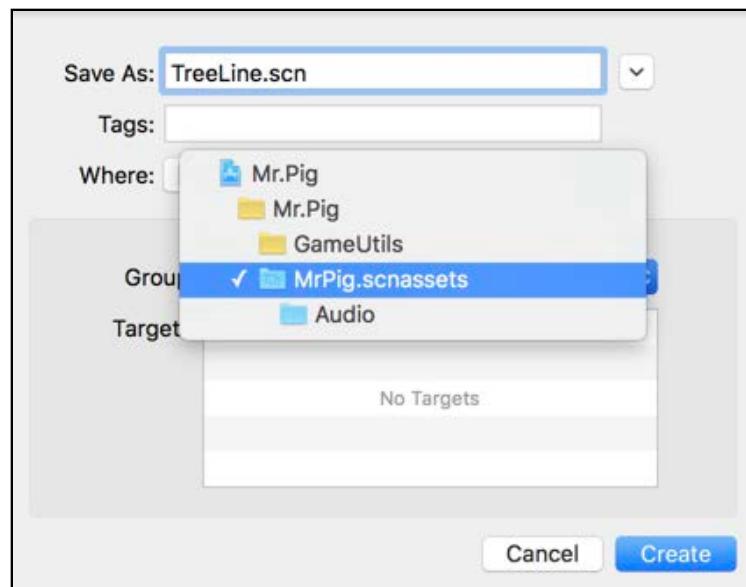
In this section, you'll create two different groups of trees: a tree line and a tree patch.

You'll use the tree line as a border around the whole park, essentially boxing Mr. Pig in. Then you'll use tree patches to create a few groups of trees to give the scene a park-like feel.

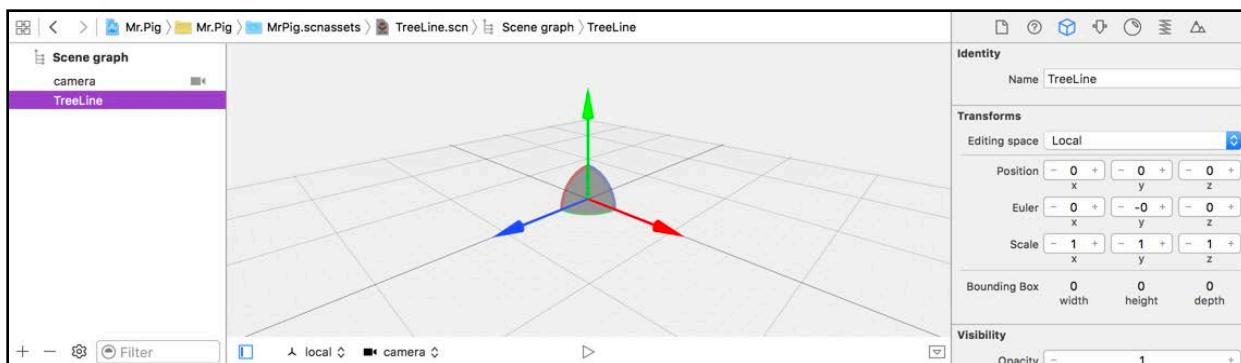
Creating the tree line

Instead of planting little trees one by one, you'll take a smarter approach. You'll create reusable scenes comprised of a bunch of trees, and then use those as reference nodes in your game scene.

Start off by dragging an empty **SceneKit Scene File** from the File Template Library into the root folder of your project under the Project Navigator. Name the new scene **TreeLine** and place it under **MrPig.scnassets**:



Inside **TreeLine scn**, create an **empty** node and name it **TreeLine**.



This will be your container node for all the trees in this scene.

Use the following grid pattern to build the tree line.

| | | X | | | | | | | | | | |
|---|----|----|----|----|----|----|---|---|---|---|---|---|
| | | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
| Z | -1 | S | M | S | M | S | M | S | M | S | M | S |
| | 0 | M | L | M | L | M | L | M | L | M | L | M |
| | 1 | S | M | S | M | S | M | S | M | S | M | S |

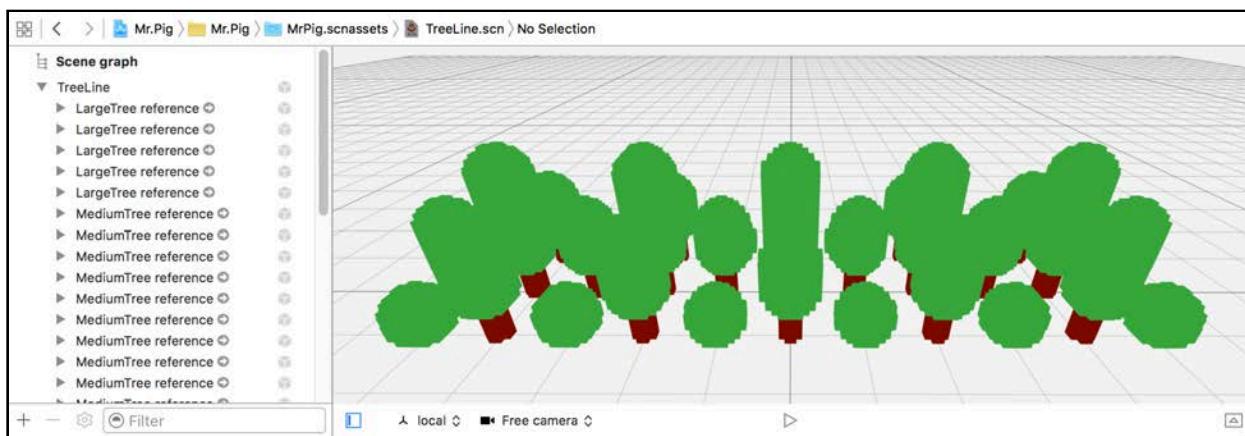
What exactly does that grid mean? Each cell holds a tree element and indicates which size to place where.

- **Columns:** Indicates the x position for where you'll place the tree element
- **Rows:** Indicates the z position for where you'll place the tree element
- **S:** Represents a **SmallTree** reference node
- **M:** Represents a **MediumTree** reference node
- **L:** Represents a **LargeTree** reference node

As an example, for row 1 and column 1 you drag and drop a **SmallTree** reference node from the Media Library into the scene and position it at (x:-5, y:0, z:-1). Remember, y=0 places the tree on the grassy surface.

To speed things up, hold the Option and Command keys as you drag to create duplicates that snap to the grid.

Once you're done, your tree line should look something like this:

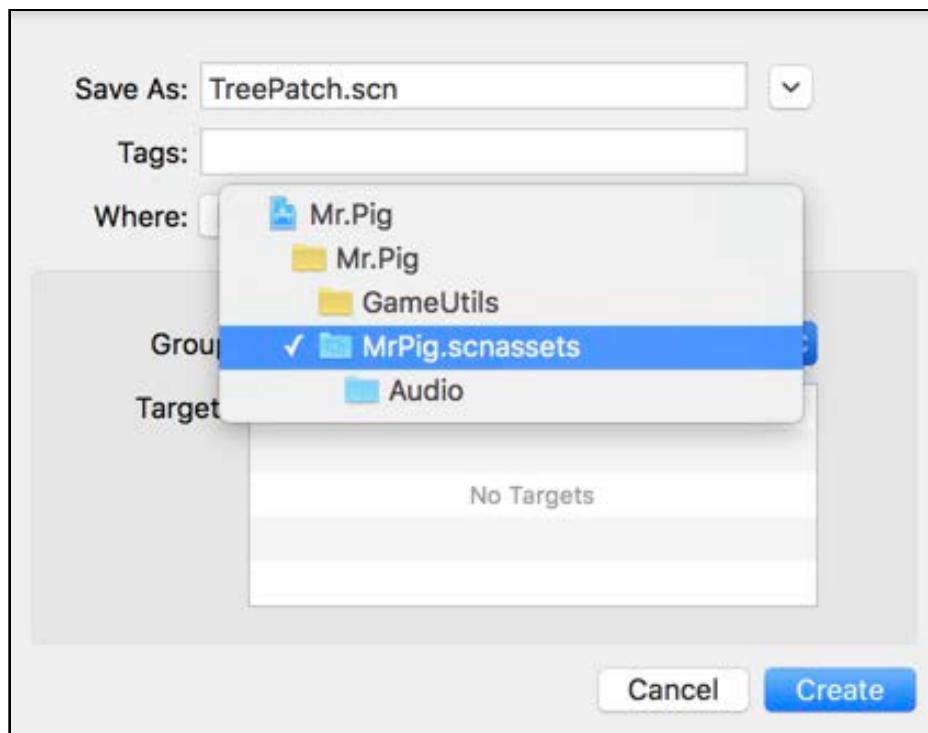


Make sure all the trees are placed under the **TreeLine** container node, and remember to remove that default **camera** because you're going to use this scene as a reference node.

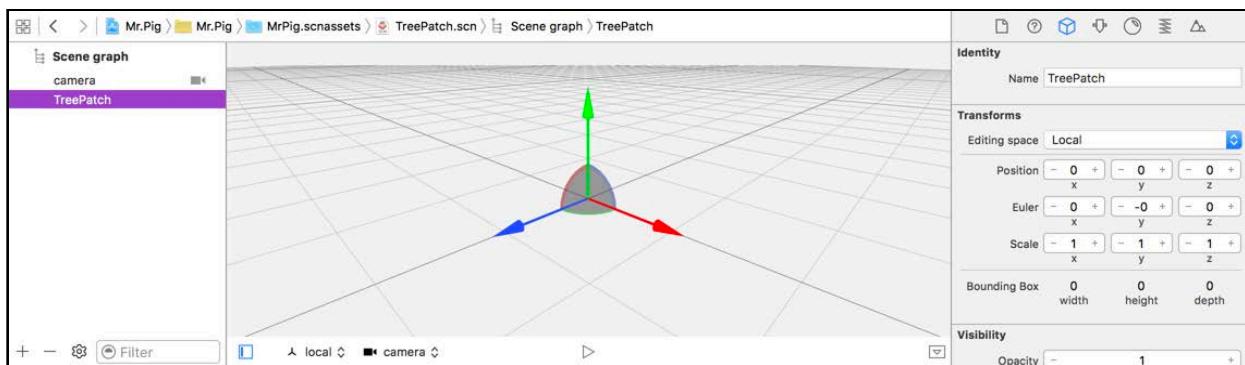
Create the tree patch

You are going to repeat the same steps to create a patch of trees that you can use as a reference node.

Drag another empty **SceneKit Scene File** from the File Template Library into your project. Name this one **TreePatch**, and make sure you place it under **MrPig.scnassets**.



Create an empty node and name it **TreePatch**. This will be a container node for all the trees in this scene.

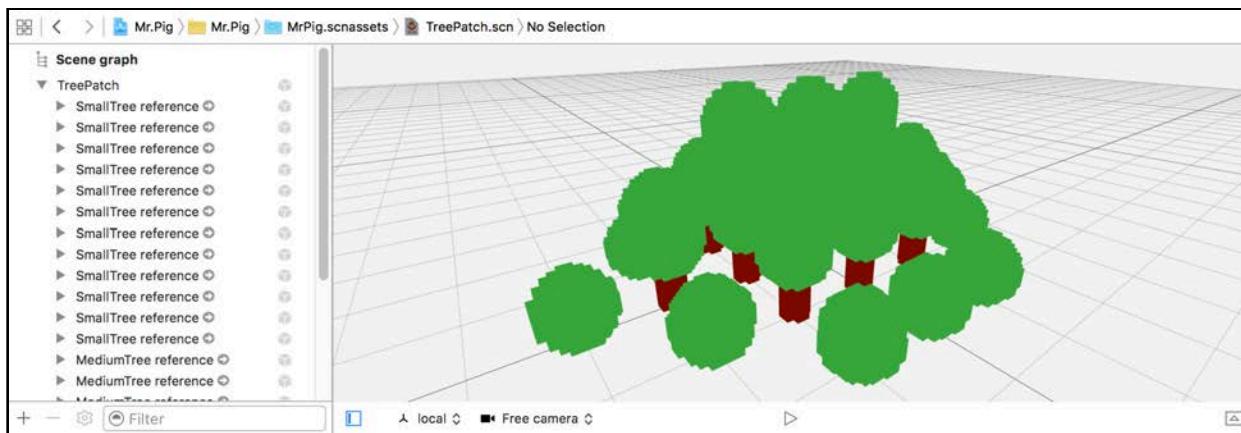


Use the following grid pattern to build the tree patch.

| | X | | | | |
|---|----|-----------|-------|---|---|
| | -2 | -1 | 0 | 1 | 2 |
| Z | -3 | | S | | |
| | -2 | | S M S | | |
| | -1 | S M L M S | | | |
| | 0 | S M L M S | | | |
| | 1 | S M L M S | | | |
| | 2 | S M S | | | |
| | 3 | | S | | |

This works exactly the same as before.

Once done, your tree patch should look something like this:

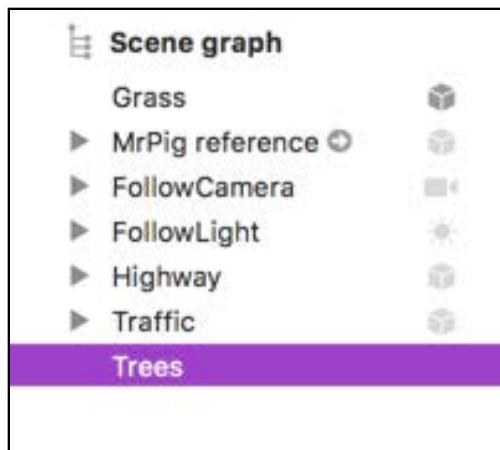


Make sure all the trees are placed under the **TreePatch** container node, and also remember to remove the **camera** once you're done because this scene is just a reference node.

Adding the tree line

Now that you've got those tree reference nodes ready, it's time to drop them into your game scene. Soon it'll look like a charming park with just a hint of fresh exhaust fumes hanging in the air. :]

Select **MrPig.scnassets/GameScene.scn** and make sure nothing is selected under your scene graph. Create an empty node named **Trees**.



This will be the container node for all the trees you're about to add to the game scene, so make sure you drag all the tree nodes under this container node.

This next part might be somewhat challenging because settings details are not included. However, I think you're ready for less detail by now.

You're about to add the tree lines. Use the following image as a reference:



The orange highlighted trees should give you a good indication of the desired result.

Start off by dragging and dropping a single **TreeLine** reference node from the Media Library into your scene. Copy the rest of the tree line from this first reference node by holding **Option** as you drag.

Use the following positions and rotations to place each block of trees at the correct location and orientation in the game scene.

The tree lines in the front, near Mr. Pig:

- **Position:** (x:0, y:0, z:7), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:-7, y:0, z:3), **Euler:** (x:0, y:90, z:0).
- **Position:** (x:7, y:0, z:3), **Euler:** (x:0, y:90, z:0).
- **Position:** (x:-14, y:0, z:-1), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:14, y:0, z:-1), **Euler:** (x:0, y:0, z:0).

The tree lines between the highways:

- **Position:** (x:-14, y:0, z:-8), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:14, y:0, z:-8), **Euler:** (x:0, y:0, z:0).

The tree lines in the back:

- **Position:** (x:18, y:0, z:-19), **Euler:** (x:0, y:90, z:0).
- **Position:** (x:-18, y:0, z:-19), **Euler:** (x:0, y:90, z:0).
- **Position:** (x:-11, y:0, z:-23), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:0, y:0, z:-23), **Euler:** (x:0, y:0, z:0**).
- **Position:** (x:11, y:0, z:-23), **Euler:** (x:0, y:0, z:0).

Note: Remember to put all the copied nodes under the **Trees** container node.

Adding the tree patches

Now, follow the same process as before to recreate the three **TreePatches**.



Start off by dragging and dropping a single **TreePatch** reference node from the Media Library into your scene. Copy the rest from this node as needed, using the following positions and rotations:

- **Position:** (x:10, y:0, z:-17), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:-10, y:0, z:-17), **Euler:** (x:0, y:0, z:0).
- **Position:** (x:0, y:0, z:-17), **Euler:** (x:0, y:90, z:0).

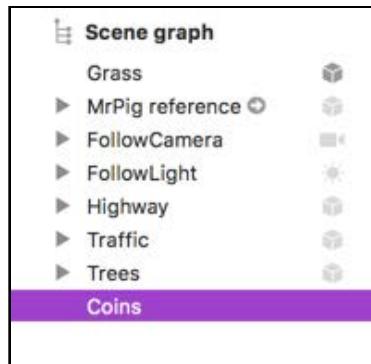
Again, make sure to move these new tree patch reference nodes under the **Trees** container node you created earlier.

Add coins

Everybody knows that little piggies are avid coin collectors. Mr. Pig is no different. He even takes his obsession to new heights by risking his life to search for shiny lost coins in the park.

Your mission is to prevent major disappointment for the little pig by adding some coins to your game scene. :]

Start off by creating an empty node and name it **Coins**. As before, this will be the container node for all the coins you'll add to the scene.



Now, drag and drop a **Coin** reference node from the Media Library into the game scene. Make three other copies of this node, and use the following positions for the coins:

- **Position:** (x:0, y:0.5, z:-8).
- **Position:** (x:0, y:0.5, z:-21).
- **Position:** (x:-14, y:0.5, z:-20).
- **Position:** (x:14, y:0.5, z:-20).

Make sure all the coins are under the **Coins** container node. Your scene should now look like this:



Excellent! You're almost done with this chapter. Do one last build and run to check that your game looks like this:



The game now starts up with the splash scene; once the player taps to play, it transitions into the game scene and you find yourself looking at pretty park. It even has traffic, trees and most importantly, coins for Mr. Pig. :]

Where to go from here?

Good job! You've reached the end of this chapter. You can find the final project for this point under **projects/final/Mr.Pig/**.

There are a few things in this chapter that you should take away:

- You're now starting to apply your skills in a methodical approach when creating complex scenes. Keeping organized is just as important as coding or gameplay. This will become second nature — if it's not already.
- You learned the importance of using reference nodes inside of reference nodes to turn hard work into child's play. Think back to how you planted a park's worth of trees in a matter of minutes.
- You also learned about boosting your game performance by restricting the cast of your shadows. There's also the lesson of moving the light source with the active camera view while keeping the shadows in view.

The game is adorable but still pretty boring at this point because there's nothing to do.

In the next chapter, you'll learn all about actions and how to use them within SceneKit to make traffic move, coins bounce and Mr. Pig jump! So hurry back after a well-deserved break. :]

Chapter 21: Actions

Chris Language

Getting started

Your game is looking great but seems to be frozen in time because there isn't any movement. In this chapter, you'll learn all about **actions** in SceneKit and how to use them to make the nodes in your game move, thus creating a dynamic 3D environment.

You'll start off by making Mr. Pig twerk like *Miley* and head-bang like *Ozzy!* :] Then, you'll add gestures and actions to make him jump on command so he can navigate the scene to pick up coins, as well as bob and weave through traffic.

You'll also make all that traffic flow from one side to another. Then finally, you'll close out this chapter by making those shiny coins spin and bounce.

Note: This chapter picks up where the previous one left off, so if you followed along, you can continue using the same project. Otherwise, you can load the starter project for this chapter from **projects/starter/Mr.Pig/**.

Actions

Actions allow you to manipulate a node's position, scale, rotation and opacity within a scene. For example, when the player swipes left, Mr. Pig should do a leftwards turn while jumping one space to the left. A swipe right should do the opposite.

These basic movements are the result of running actions in sequences (serially) and groups (in parallel) on the pig node.

You can build action sequences within the SceneKit editor by dragging and dropping actions from the Object Library into the Secondary Editor — just below the Scene Editor — when you have a node selected. From a coding perspective, you first need

to create an `SCNAction` object, setting its `timingMode` if you want, and then you can execute that action on any `SCNNode` instance by using the `runAction(_:)` method on the node.

There are four basic categories of actions at your disposal for manipulating a node's behavior in the scene: **Move**, **Scale**, **Rotate** and **Fade**. There are two more special actions used to either run actions in a **Sequence** or as a **Group**.

Note: Think back to when you first learned about physics bodies found out about the three types of physics bodies: **dynamic**, **kinematic** and **static**.

If you wanted the physics engine to take control of a node's movement and rotation, you'd set its physics body to **dynamic**.

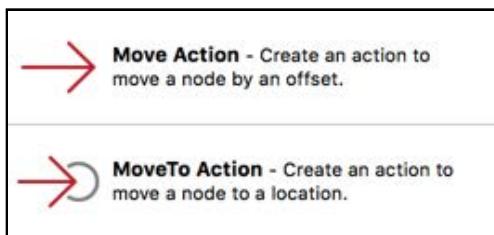
If you wanted the node to never move but still participate in the physics simulation, you'd set its physics body to **static**.

If you wanted to take control of a specific node's movement and rotation while letting it participate in the physics simulation, you'd set its physics body type to **kinematic**.

Mr. Pig is *kinematic*, which means you want to control his movement manually with actions, rather than leaving him to the will of the physics engine.

Moving actions

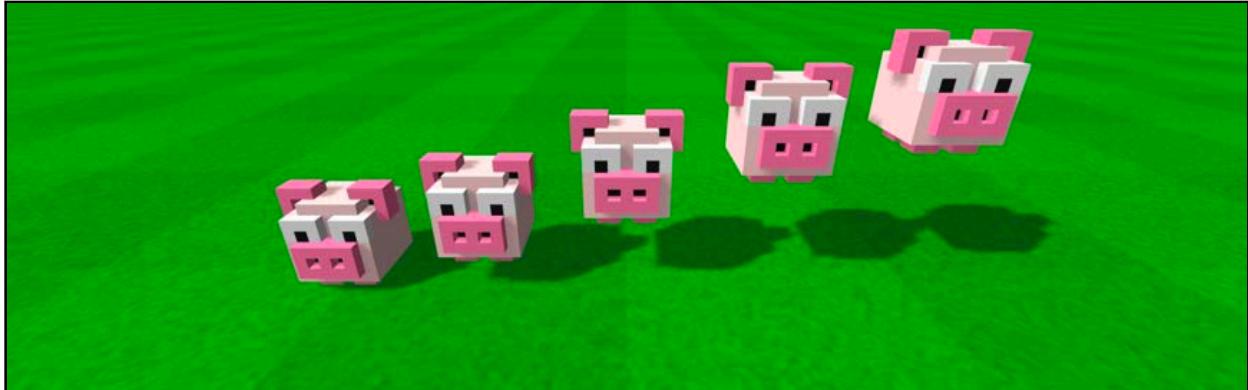
When you want to move a node from one point to another point in 3D space, **Move** actions are just the thing to use.



Take a closer look at the two types of move actions:

- **Move Action:** This moves the node by an offset from the node's *current position*.
- **MoveTo Action:** This moves the node to a *specified location* in 3D space *regardless* of the node's current position.

The following image illustrates how you'll use the **Move** action to make Mr. Pig bounce up and down:

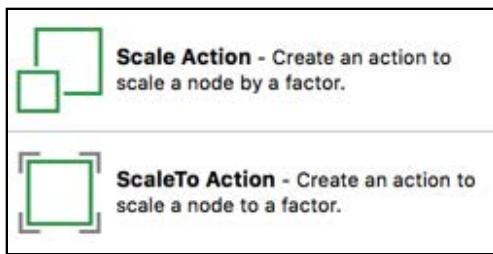


For example, the above move action moves the pig by an offset of `(x:0, y:1, z:0)` from his current position over a period of time, thus moving it upwards along the `y`-axis. To bring the pig back to earth, you'll have to run another move action, but this time you need to reverse the offset to `(x:0, y:-1, z:0)` to get him back on the ground.

You'll use the same **Move** action to make him move left, right, forward and backward.

Scaling actions

Maybe Mr. Pig is extremely allergic to bee stings, and you'd like to spice up the game with some bee swarms. :] You could use the **Scale** actions to make him swell up after he becomes a repository for some bee's stinger.



Scale actions work pretty much the same as the move actions.

- **Scale Action:** This scales the node by a factor from the node's current scale.
- **ScaleTo Action:** This scales the node to a specified scale factor, regardless of the node's current scale.

The following image demonstrates how Mr. Pig scaled from a little piglet to the massive porker he is today:

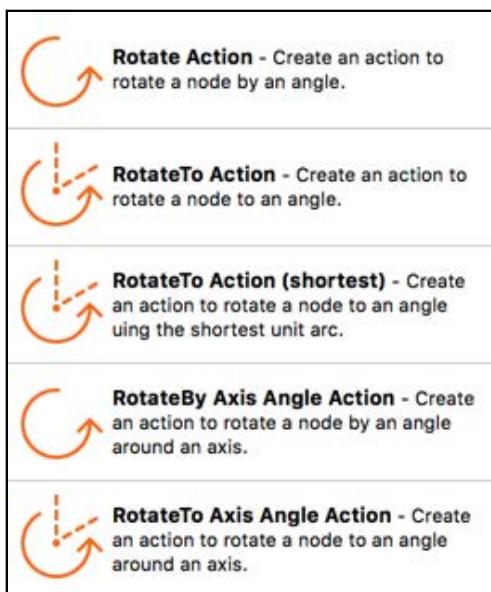


Did somebody say bacon?

You can also use scale actions to make nodes wobble by scaling each axis independently. Doing so will distort the geometry, creating an effect that you might want to use when the pig gets stung by a bee, or when he picks up a power-up — like good old Mario after he picked up that magic mushroom! :]

Rotating actions

When Mr. Pig jumps left or right, it makes sense to have him turn towards the same direction; to do that, you'll use **Rotate** actions.



There are more options for rotation than there are for move or scale actions:

- **Rotate Action:** Rotates the node by an angle offset from the node's current rotation angle.
- **RotateTo Action:** Rotates the node to a specified angle regardless of its current rotation.

- **RotateTo Action (Shortest)**: Rotates the node to a specified angle regardless of the node's current rotation. It takes the shortest possible rotation to get to the specified angle.
- **RotateBy Axis Angle Action**: This rotates the node by an angle offset on a specified axis from the node's current rotation on that axis.
- **RotateTo Axis Angle Action**: This rotates the node to a specified angle on a specified axis, regardless of the node's current rotation on that axis.

The following image shows how Mr. Pig turns from forward to backward by using the **RotateTo Action (Shortest)** over a period of time.

From left to right, Mr. Pig spins around, showing you his very cute curly tail. Awww! :]



You can also use rotate actions to make the pig look up or down or even topple over onto his back. Yes, with these controls, Mr. Pig and his world are at your command.

Fade actions

Rarely does a little pink pig fare well when struck by a vehicle. In this scenario, he goes where all pigs go when they die — piggie heaven, where there are countless coins to collect, a never-ending supply of tea, pretty flowers to smell and *no* traffic.

But there's a transition that happens when he leaves this mortal existence. You'll need to represent this with a visual so that the player knows Mr. Pig just moved onto porker heaven.

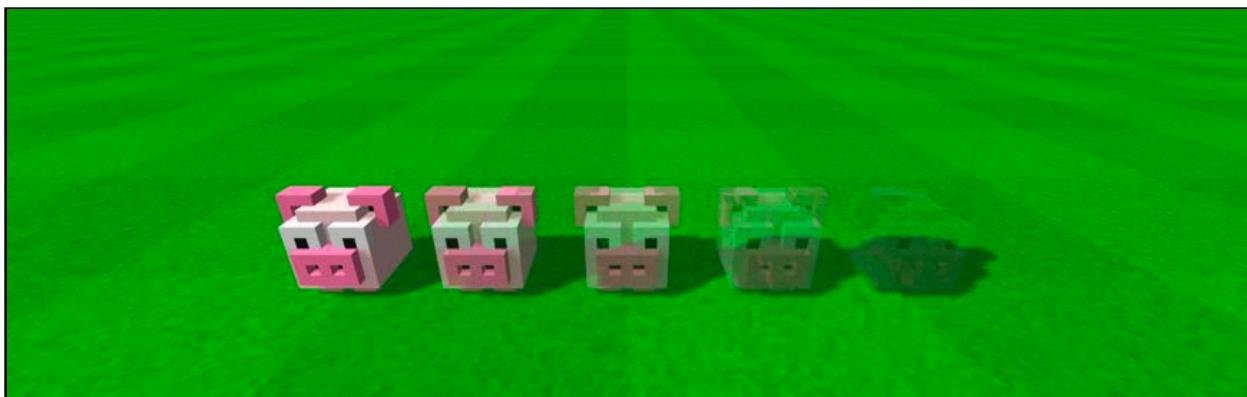
To turn our hero into a ghost, you'll use **Fade** actions to make him turn translucent.



There are a few fade actions at your disposal — take a look:

- **FadeOut Action:** Fades the opacity from its current setting to completely *invisible*.
- **FadeIn Action:** Fades the opacity from its current setting to completely *visible*.
- **FadeOpacityTo Action:** Fades the opacity to a specified value.

The following image demonstrates how Mr. Pig turns into a ghost then vanishes into thin air. From left to right, Mr. Pig fades out from vibrant visible to non-existent. Rest in peace, pig. You lived a good life...



You can also use fade actions to make nodes pulsate from visible to invisible while they are in a certain state, such as when a spaceship respawns in a shoot-em-up game.

Sequenced and grouped actions

Once you've created a bunch of basic actions, you can combine them together in sequences and groups to make actions run one after another, or together at the same time.

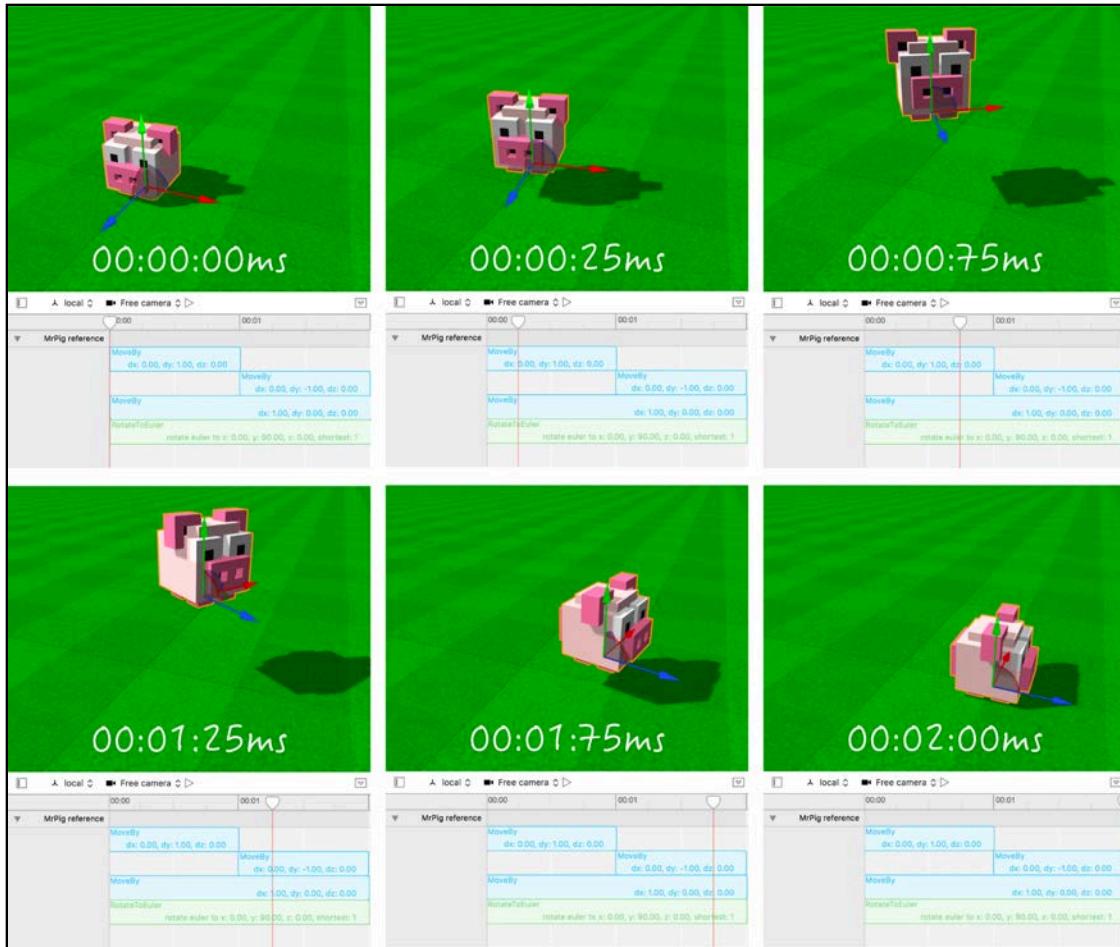
The following diagram shows the relationship between a few basic actions that will play out over a period of two seconds:



Take a closer look:

- **Actions:** The left simply names the four basic actions: bounce-up, bounce-down, move-right and rotate-right, and it shows where they are placed on the action editor timeline. More on this soon.
- **Sequence:** Inside the blue rectangle, you'll see two actions in a *sequence*. So when you progress through the timeline, the time cursor will first start the bounce-up action for one second, and once that finishes, it starts running the bounce-down action. This is called a sequence of actions.
- **Group:** Inside the red rectangle is the blue sequence of actions, along with two other actions for *move-right* and *rotate-right*. As you move down the timeline, the time cursor will start bounce-up, move-right and rotate-right at the same time, in parallel. When the timeline reaches one second, the bounce-up action completes and the bounce-down action starts. At the same time, move-right and rotate-right are still running and halfway done at that point. Once the timeline reaches the two-second mark all the actions are complete. By grouping actions together, you run them all in parallel.

The image below shows the actual animation as it plays out over time:



Take a closer look at what happens here:

1. First, by running the bounce-up and then the bounce-down actions in a sequence, you make the pig start on the ground then leap up into the air, only to drop back to the ground again.
2. He starts off in one position, then moves one space to the right of where he started by using the move-right action.
3. At the same time, our hero starts off facing forward, but then rotates so that he ends up facing right by means of the rotate-right action.

Action timing functions

SceneKit provides some basic timing functions you can use to control the progression of any action over time. When Mr. Pig jumps into the air, it has to look realistic and not robotic. You have some work ahead to make that happen.

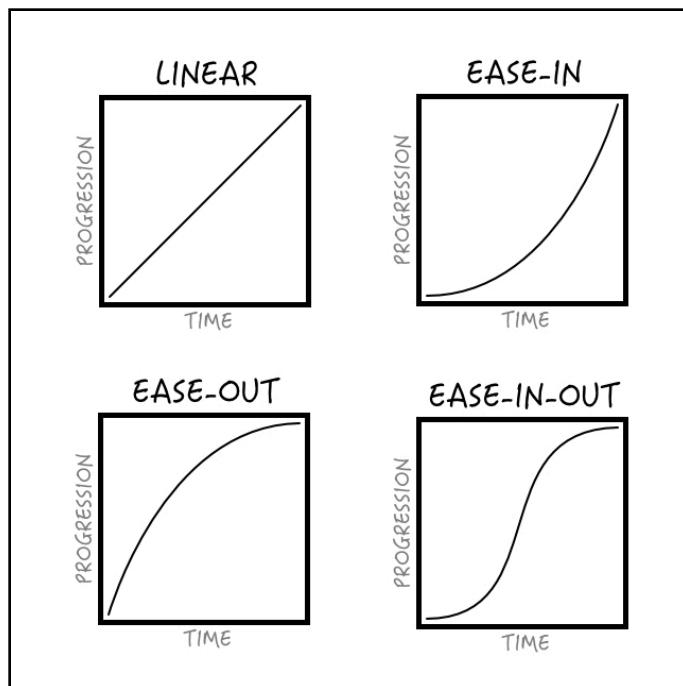
At the moment, bounce-up is merely a move action to some defined point in the air, and bounce-down is another move action that takes him to a point on the ground.

It would look strange if you played out these actions in a linear fashion; the pig would move up and down in the air, abruptly stopping at the apex in a robotic manner.

This simply is unacceptable when you consider what happens when you toss an egg into the air.

1. The egg leaves your hand at full velocity, traveling upwards into the air.
2. It continues upwards, but because of gravity's unavoidable pull, its velocity reduces as it goes.
3. At some point in time, the egg reaches a precipice where it slows to a complete standstill in mid-air.
4. It then starts its journey towards splatterdom, falling back to earth with an initial velocity of zero.
5. It continues downwards, all the while its velocity increases thanks to gravity's relentless pull.
6. Eventually, it reaches a maximum velocity, or it would if there wasn't some force acting on it to stop it, like the ground.
7. Lastly, it shatters to make a terrific mess, which is a physics lesson for another day.

To simulate this behavior in actions, SceneKit gives you four basic timing functions:



- **Linear:** This is the default timing function used for all actions. The action will play out at the same speed throughout its duration.
- **Ease-In:** This timing function gives the action a slow start, eventually accelerating to its full speed for the rest of the duration.
- **Ease-Out:** This starts the action at its full speed and slows as it reaches the end.
- **Ease-In-Out:** This gives the action a slow start that reaches full speed halfway through. Then it slows as it approaches the end.

To accurately simulate gravity for Mr. Pig's jump action, you'll use a combination of these timing functions.

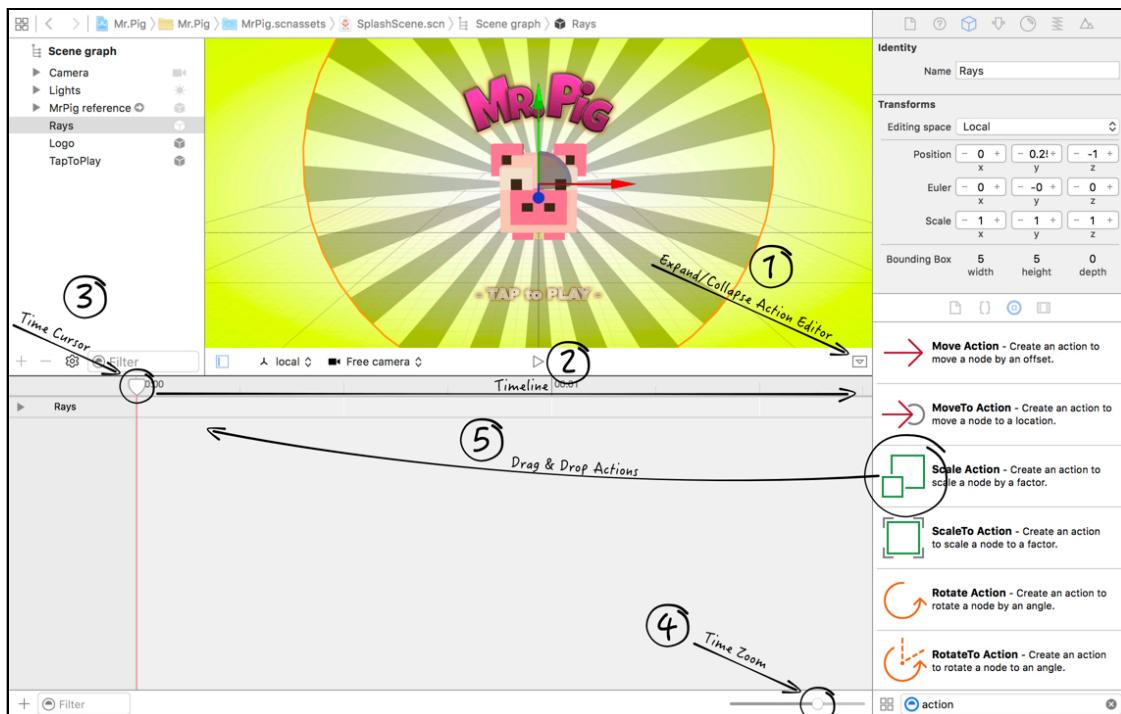
Note: You can make use of the `timingMode` property on an `SCNAction` to set function in code.

The action editor

Now that you know all about actions, it's time to see them... in action! :]

Xcode has a hidden feature known as the **Secondary Editor**. In the case of the SceneKit editor, this secondary editor is the **actions editor** for nodes in a scene.

Take a look at the following image:



There are a few numbered points to go through:

1. **Expand/Collapse Action Editor:** This is the secondary editor button that you need to press to expand or collapse the actions editor.
2. **Timeline:** This is the timeline, and there's a grid below it that shows when actions take place. Time progression increases as you move to the right.
3. **Time Cursor:** Drag this cursor across the timeline to see the resulting actions running on your nodes in the scene.
4. **Time Zoom:** Use this slider to zoom in or out on the timeline to make editing easier for yourself.
5. **Drag & Drop Actions:** To add actions to a node, you simply drag and drop them from the Object Library into the action editor at the time you would like to see the action take place.

Note: At the time of writing this chapter, there appears to be a few bugs in the SceneKit editor that relate to actions. Sometimes, when you go back and try to edit existing actions on a node, things can go horribly wrong. Xcode might even crash on you. If you run into this problem, you may find it best to delete the actions and re-create them from scratch.

Animate the rays

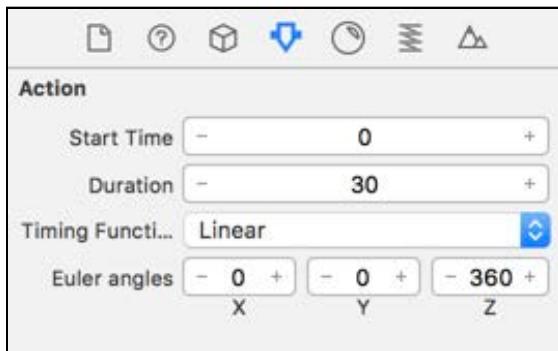
Now it's time to apply your knowledge and make the rays spin. :]

Start by opening your project and select **MrPig.scnassets/SplashScene scn** to bring up the SceneKit editor. Select the **Rays** node in the scene graph and open up the actions editor for it.

Drag and drop a **Rotate Action** from the Object Library into the actions editor. Make sure to drop it so that the action starts off at time **0:00**:



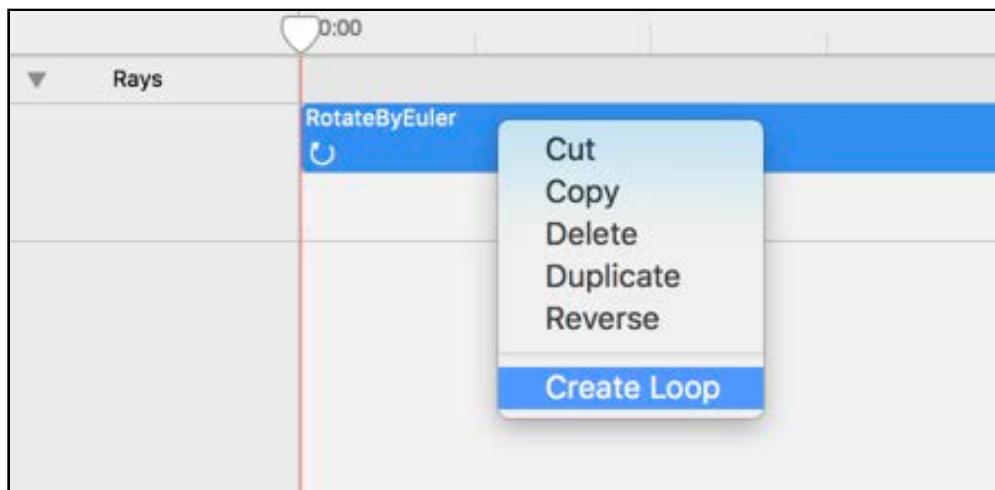
With the action still selected, select the Attributes Inspector:



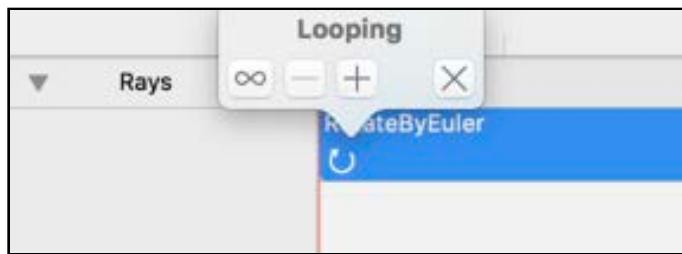
Here, you set the properties available for both the action and the node. Let's take a closer look at the available properties you can adjust for this action:

- **Start Time:** This sets the starting point for when the action should run. Leave this at its default of 0.
- **Duration:** This sets the duration of how long the action will run. Set this to 30 so this action runs for 30 seconds in total.
- **Timing Function:** This sets the timing function to use while running the action. Leave this at its default of Linear.
- **Euler angles:** This sets the offset of the node's current once the action completes. Leave **X** and **Y** at 0, but be sure to set the **Z** value to 360, or else nothing will happen.

Now you want to loop the action so that it runs forever, effectively keeping those rays spinning for an eternity. **Right-click** on the action and select **Create Loop**:

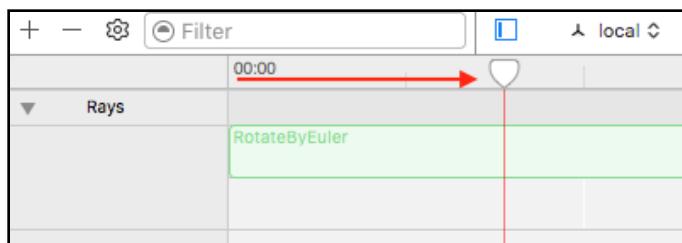


This will show another little **Looping** pop-up:



Click **∞** (infinity) so that it turns blue and then click outside of the menu to close it. *Don't* click the **X** button because it'll cancel your loop option selection.

You're all done! Try dragging the time cursor to the right and left to see a preview of your spinning rays.

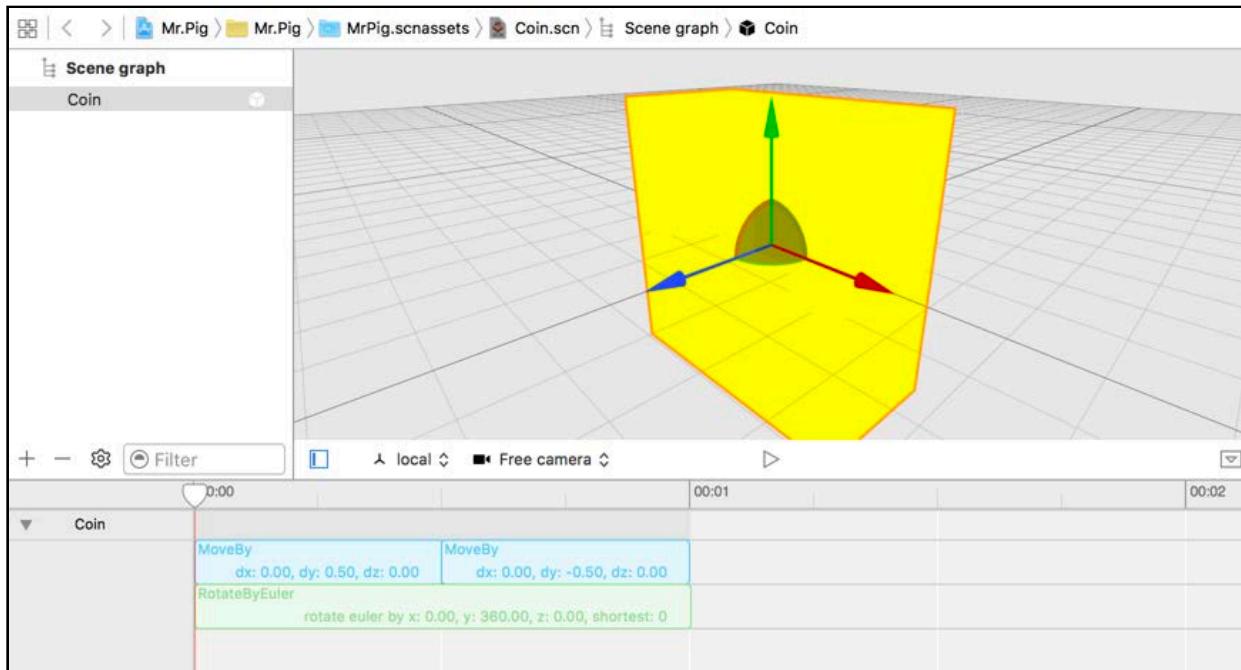


Note: You can access the looping options again by simply **right-clicking** on a looping action and selecting **Edit Loop**.

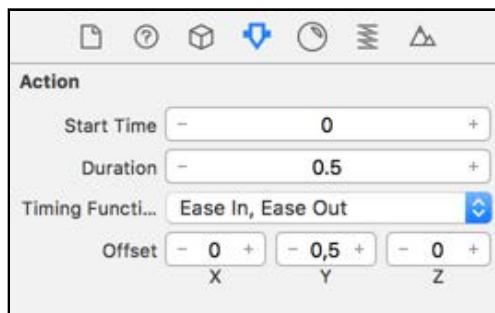
Animating the coins

Another fun little animation you'll add is one that makes the coins in your game scene spin and bounce up and down, making them easy for our hero to see! :]

First, select the **MrPig.scnassets/Coin.scn** reference node, then make sure you have the **Coin** node selected and the actions editor open. Drag and drop two instances of **Move Action** one after another. Then, drag and drop a **Rotate Action** parallel in there by placing it below the move actions you added:

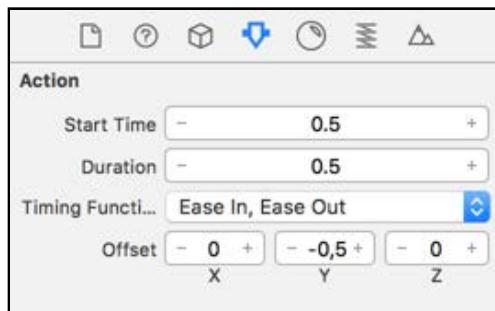


Select the first **Move Action** and set the **Start Time** to 0 and **Duration** of 0.5. Set the **Timing Function** to **Ease In, Ease Out**, and set the **Offset** to (x:0, y:0.5, z:0).



This will move the coin upwards, easing in and out as it reaches the end of the action for a more natural look.

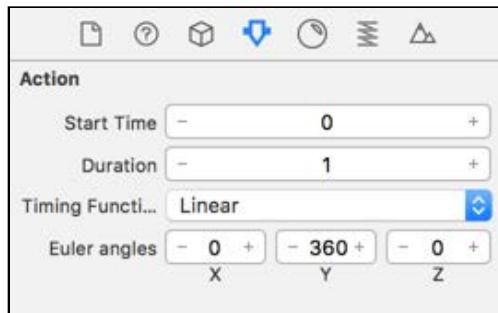
Select the next **Move Action**. This time, set its **Start Time** to 0.5 to start as soon as the previous action ends. Also set its **Duration** to 0.5, its **Timing Function** to **Ease In, Ease Out** and **Offset** to x:0, y:-0.5, z:0:



This will move the coin downwards, easing it in then out again as it reaches the end of the action.

Now select the **Rotate Action**. It starts at the same time as the first move action and runs for the same duration as both move actions combined. Set its **Start Time** to 0 and **Duration** to 1.

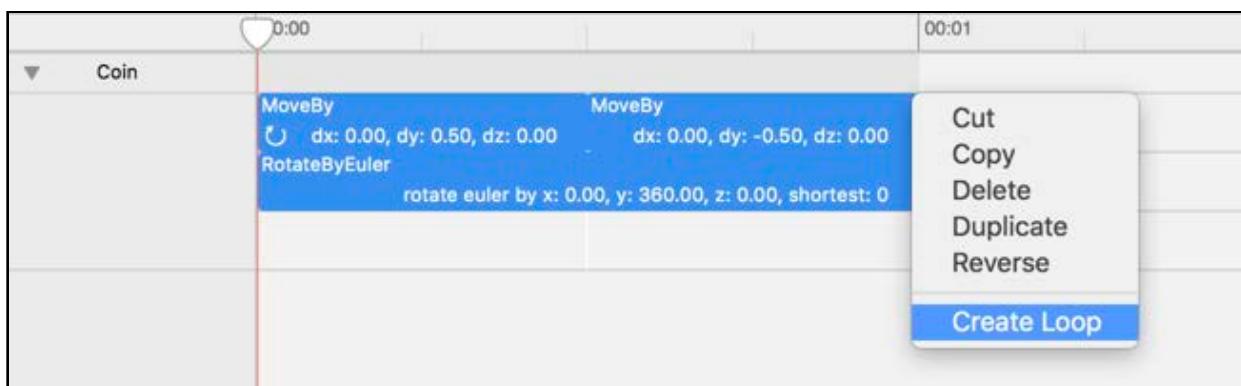
Leave its **Timing Function** to **Linear** so that it spins at a constant rate. Finally, set the **Euler Angle** to (x:0, y:360, z:0) so the coin does a full 360 degree spin in one turn of animation:



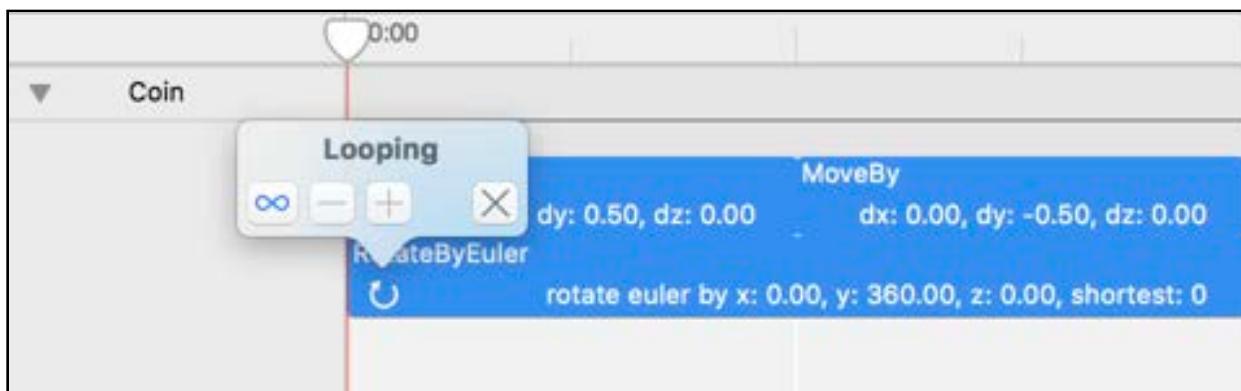
Now make the coin spin forever.

First, make sure you've got all the actions selected; do this by pressing **Shift** key while clicking on each action. **Right-click** to reveal the list of options available.

Select the **Create Loop** option:



Another little pop-up will appear with the **Looping** options:



Select the ∞ (infinity) button, which will turn blue. Click outside of this box to confirm your selection. If you click the \times button, you'll delete the loop. This infinite selection means the actions in the loop run forever.

Feel free to use the time cursor to preview your work so far.

Challenge

Here's a fun little challenge to test yourself — the twerk challenge! Hey, where are you going? I didn't mean *you* have to twerk. (But kudos if you're one of the select few who can actually do it without looking silly.)

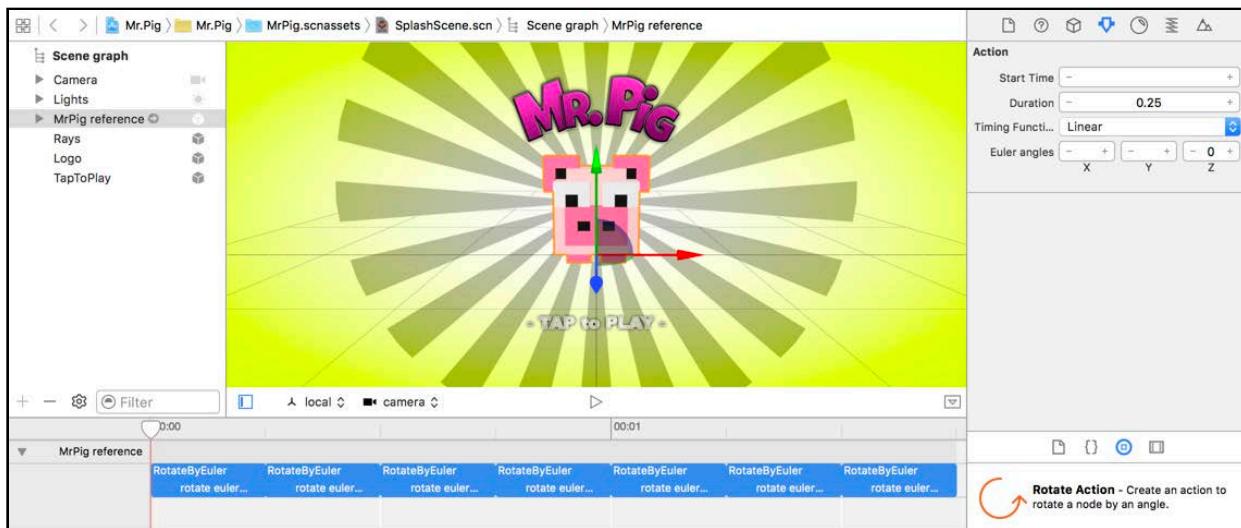
The idea here is to make Mr. Pig twerk and show off that curly little tail in the splash screen, not for you to show off *your* sweet dance moves. :]

Go into **MrPig.scnassets/SplashScreen.scn** to start your challenge. You don't want to make the reference node twerk, or else Mr. Pig will constantly twerk in the game scene and that might be considered obscene.

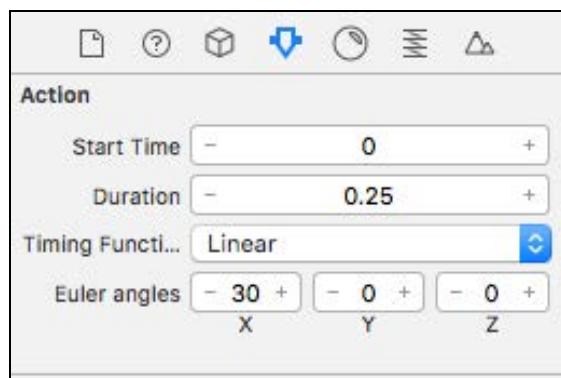
Animating the pig

You're about to make the pig twerk! Relax, it's much easier than one would think. First, select the **MrPig** reference node in the splash scene and bring up the actions editor.

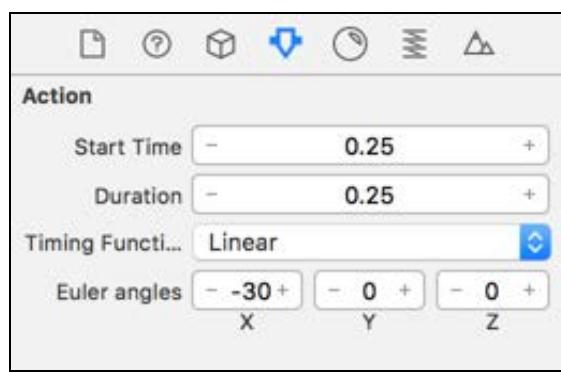
1. Connect 7 **Rotate Actions** in a sequence, and set all of them to a duration of **0.25s**.



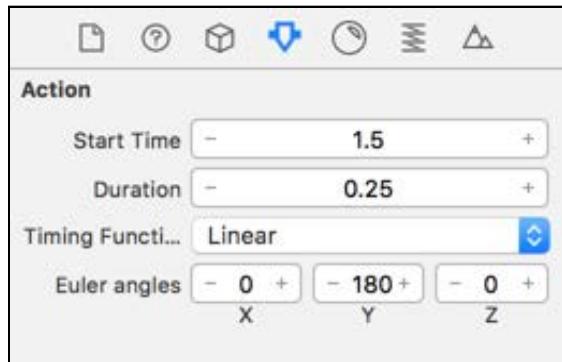
- Set the first rotate action so it tilts the pig forward by rotating it 30° on its x-axis.



- Then set the next rotate action to tilt the pig backward by rotating it -30° on its x-axis.

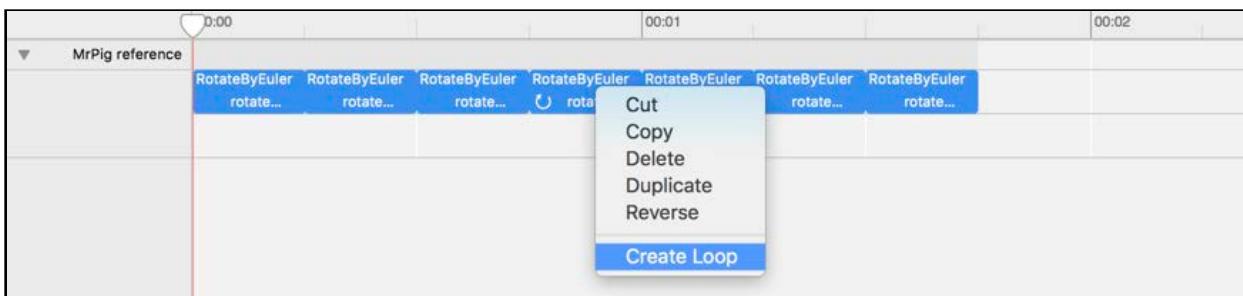


- Repeat steps two and three for the remaining actions except the last one.
- For the very last rotate action, you want the node to do a full 180° turn so that the pig shows you its tail-end. Do this by rotating it 180° on the y-axis.



- If you scrub the time cursor along the timeline, the pig will head-bang, and then flip around to show you his tail. Perfect! :]

The next bit is easy. Simply select all the actions, right-click and select the **Create Loop** option.



- Make sure to select the ∞ (infinity) loop option when you see the **Looping** options.



Note: You can find the solution for this little challenge under **projects/challenge/Mr.Pig/**.

It's a good time for a build and run.



Your splash scene should look much more attractive now, with the spinning rays and a very energetic twerking Mr. Pig! :]

Now you see that it's easy to give your characters a bit of attitude with just a few, simple animations.

Coded actions

Now that you know how to create and use actions using the built-in Xcode actions editor, this section will focus more on how to create and use actions in code. You're getting into the thick of it now!

- You'll start by creating two actions that will ultimately make the traffic move.
- Then you'll create a few basic actions for gestures that'll make the pig jump around the scene.

Finally, you'll create a game over action to use when Mr. Pig meets his fate against the moving traffic.

Animating the traffic

There are two highways, one with traffic flowing left and another with traffic flowing right.

A **Move Action** should meet the need to make the cars and buses move, as this will move the traffic a certain distance over a period of time.

Remember there's also a bus lane filled with slower moving vehicles. Instead of creating multiple actions for the two speeds, you're simply going to run the same action on the different vehicles and adjust the action's speed.

Note: If you are an Extreme Home Makeover fan, you might find it fitting to take a break at this moment and shout: "Move that Bus! Move that Bus! Move that Bus!" :]

In code, actions are represented by instances of the `SCNAction` class — of course there are class methods to create all the various actions you've seen at in the Object Library.

For instance, **Move Action** can be created in code using the `SCNAction.move(by:duration:)` class method.

Open **ViewController.swift** and add the following action properties to `ViewController`:

```
var driveLeftAction: SCNAction!
var driveRightAction: SCNAction!
```

These two properties will store the move left and move right actions so you can reuse them at will.

Add the following to `setupActions()`:

```
driveLeftAction = SCNAction.repeatForever(SCNAction.move(by:
    SCNVector3Make(-2.0, 0, 0), duration: 1.0))
driveRightAction = SCNAction.repeatForever(SCNAction.move(by:
    SCNVector3Make(2.0, 0, 0), duration: 1.0))
```

The `SCNAction.repeatForever(_:_)` class method creates a special action that will simply loop, or rather repeat, another action forever. The `SCNAction.move(by:duration:)` class method creates an action that will move the node by a specified vector over a certain duration.

Now put these two new actions to good use by adding the following code to `setupTraffic()`:

```
// 1
for node in trafficNode.childNodes {
```

```
// 2 Buses are slow, the rest are speed demons
if node.name?.contains("Bus") == true {
    driveLeftAction.speed = 1.0
    driveRightAction.speed = 1.0
} else {
    driveLeftAction.speed = 2.0
    driveRightAction.speed = 2.0
}

// 3 Let vehicle drive towards its facing direction
if node.eulerAngles.y > 0 {
    node.runAction(driveLeftAction)
} else {
    node.runAction(driveRightAction)
}
```

The `setupTraffic()` method is already being called from `viewDidLoad()` so you don't need to worry about that, but take a closer look at what the actual code does:

1. At this point, `setupNodes()` has already initialized `trafficNode`, which is attached to the **Traffic** node in the game scene. The `childNodes` property of `SCNNNode` returns a list of child nodes for you to iterate through. This will essentially be a list of all the vehicle nodes on the highways.
2. If the node is a bus, you set the `SCNAction.speed` to be `1.0`, otherwise you set it to `2.0` to run the action for the smaller vehicles twice as fast.
3. Based on the assumption that you only have traffic moving left and right, this does a crude check to see which direction the vehicle is facing. It then executes the appropriate drive action on the node.

Do another build and run, then start the game by tapping on the splash scene:



The traffic is moving. Oh, goody! :]

But wait there's a problem, all of the traffic drives off the screen leaving a safe, empty road for Mr. Pig to cross. At this rate, crossing the road hardly qualifies as heroic.

Don't worry, this is a small little problem that you'll tackle when you're handling updates within the game render loop. That won't be in this chapter, so for now, just accept the current state.

Adding pig movement

Your next task is to make that pig jump like a little flea. Mr. Pig will need to be quick on his feet — able to jump forward, backward, left and right.

To accomplish this, you'll create a whole bunch of little actions that you'll sequence and group together.

Add the following action properties to ViewController:

```
var jumpLeftAction: SCNAction!
var jumpRightAction: SCNAction!
var jumpForwardAction: SCNAction!
var jumpBackwardAction: SCNAction!
```

These are the four resulting actions that will make the pig jump in various directions.

Add the following to bottom of setupActions():

```
// 1
let duration = 0.2

// 2
let bounceUpAction = SCNAction.moveBy(x: 0, y: 1.0, z: 0, duration:
duration * 0.5)
let bounceDownAction = SCNAction.moveBy(x: 0, y: -1.0, z: 0, duration:
duration * 0.5)

// 3
bounceUpAction.timingMode = .easeOut
bounceDownAction.timingMode = .easeIn

// 4
let bounceAction = SCNAction.sequence([bounceUpAction, bounceDownAction])

// 5
let moveLeftAction = SCNAction.moveBy(x: -1.0, y: 0, z: 0, duration:
duration)
let moveRightAction = SCNAction.moveBy(x: 1.0, y: 0, z: 0, duration:
duration)
let moveForwardAction = SCNAction.moveBy(x: 0, y: 0, z: -1.0, duration:
duration)
let moveBackwardAction = SCNAction.moveBy(x: 0, y: 0, z: 1.0, duration:
duration)

// 6
let turnLeftAction = SCNAction.rotateTo(x: 0, y: convertToRadians(angle:
-90),
z: 0, duration: duration, usesShortestUnitArc: true)
let turnRightAction = SCNAction.rotateTo(x: 0, y: convertToRadians(angle:
90),
z: 0, duration: duration, usesShortestUnitArc: true)
let turnForwardAction = SCNAction.rotateTo(x: 0, y:
convertToRadians(angle: 180),
z: 0, duration: duration, usesShortestUnitArc: true)
let turnBackwardAction = SCNAction.rotateTo(x: 0, y:
convertToRadians(angle: 0),
z: 0, duration: duration, usesShortestUnitArc: true)

// 7
jumpLeftAction = SCNAction.group([turnLeftAction, bounceAction,
moveLeftAction])
jumpRightAction = SCNAction.group([turnRightAction, bounceAction,
moveRightAction])
jumpForwardAction = SCNAction.group([turnForwardAction, bounceAction,
moveForwardAction])
jumpBackwardAction = SCNAction.group([turnBackwardAction, bounceAction,
moveBackwardAction])
```

Quite the screenfull of code. How about a breakdown?

1. Using a variable for the duration simply makes your life easier once you start tweaking action animation times. You'd typically work in fragments of a specific duration, and this variable simplifies it so that you can use simple math in the rest of the code to specify a fragment of the original duration.

2. This creates the two basic actions that bounce the pig up and down, similar to the visual examples demonstrated at the beginning of this chapter.
3. This updates the timing functions for the bounce actions so that when they run in a sequence, the pig will have a realistic jump animation with some hang-time! :]
4. This creates `bounceAction` by using the `bounce up` and `bounce down` actions in sequence.
5. This creates four move actions using `SCNAction.moveBy(x:y:z:duration:)` to move in every direction.
6. This creates four rotation actions using `SCNAction.rotateTo(x:y:z:duration:usesShortestUnitArc:)` — one for rotating in each direction.
7. Finally, this creates the four jump actions by combining the turn, bounce and move actions into a group, which will run all three actions in parallel.

Add movement gestures

All the actions are now ready to go. What's left is to get Mr. Pig to respond to some gestures so that you can run the appropriate actions for the player.

First, you need to run actions when you detect a swipe, so add `handleGesture(_:)` to `ViewController`:

```
// 1
func handleGesture(_ sender: UISwipeGestureRecognizer) {
    // 2
    guard game.state == .playing else {
        return
    }
    // 3
    switch sender.direction {
        case UISwipeGestureRecognizerDirection.up:
            pigNode.runAction(jumpForwardAction)
        case UISwipeGestureRecognizerDirection.down:
            pigNode.runAction(jumpBackwardAction)
        case UISwipeGestureRecognizerDirection.left:
            if pigNode.position.x > -15 {
                pigNode.runAction(jumpLeftAction)
            }
        case UISwipeGestureRecognizerDirection.right:
            if pigNode.position.x < 15 {
                pigNode.runAction(jumpRightAction)
            }
        default:
            break
    }
}
```

Take a deeper look at exactly what happens here:

1. This defines a typical gesture handler and receives a `UIGestureRecognizer` as an input. You'll need to inspect this element to determine the exact gesture details.
2. This keeps the game state in mind. Typically you're not interested in any gestures unless the game is in a `.playing` state, so ignore all gesture events when the game state is something else.
3. This inspects direction of the gesture recognizer to determine the direction of the player's swipe. Then, it executes the correct jump action on the pig node, which will make the pig jump in the direction of the swipe. There's also a small check when jumping left and right to prevent Mr. Pig from jumping out of the play area.

Now create four basic gestures for your game by adding the following to `setupGestures()`:

```
let swipeRight = UISwipeGestureRecognizer(target: self,
    action: #selector(ViewController.handleGesture(_:)))
swipeRight.direction = .right
scnView.addGestureRecognizer(swipeRight)

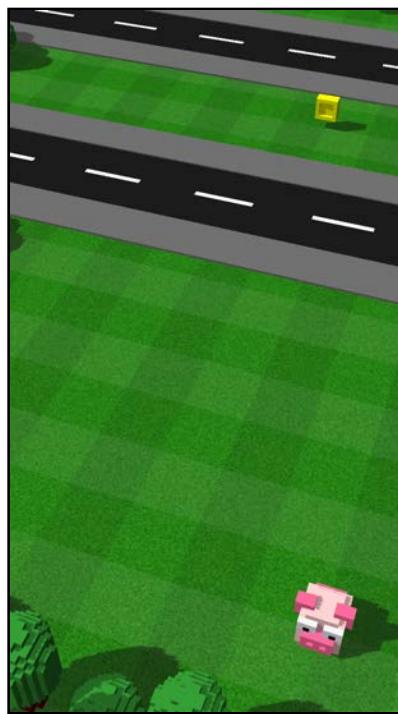
let swipeLeft = UISwipeGestureRecognizer(target: self,
    action: #selector(ViewController.handleGesture(_:)))
swipeLeft.direction = .left
scnView.addGestureRecognizer(swipeLeft)

let swipeForward = UISwipeGestureRecognizer(target: self,
    action: #selector(ViewController.handleGesture(_:)))
swipeForward.direction = .up
scnView.addGestureRecognizer(swipeForward)

let swipeBackward = UISwipeGestureRecognizer(target: self,
    action: #selector(ViewController.handleGesture(_:)))
swipeBackward.direction = .down
scnView.addGestureRecognizer(swipeBackward)
```

This registers the `handleGesture(_:)` method as the event handler for the swipe up, down, left and right gestures, so that when the player makes a swipe gesture, `handleGesture(_:)` triggers further action.

Do a build and run and go test out the gesture control system:



Once your game starts, you should be able to swipe in any direction, and Mr. Pig will follow your every command. Excellent! :]

But wait there's another problem, the camera isn't following the pig, so he's able to jump out of sight. Don't worry, this is just another small little problem to sort out when you get to the part about handling updates within the game render loop.

Creating the game over sequence

You're almost done with this chapter. There's just one more action to create: the triggerGameOver action!

This little action comprises a few sub-actions that will send our beloved hero to piggie heaven, and then trigger a call to startSplash() to show the splash scene again.

Start off by adding the following action property to ViewController:

```
var triggerGameOver: SCNAction!
```

This stores the final action you'll run to trigger the game over sequence.

Add the following to the bottom of setupActions():

```
// 1
let spinAround = SCNAction.rotateBy(x: 0, y: convertToRadians(angle: 720), z: 0, duration: 2.0)
let riseUp = SCNAction.moveBy(x: 0, y: 10, z: 0, duration: 2.0)
let fadeOut = SCNAction.fadeOpacity(to: 0, duration: 2.0)
```

```

let goodByePig = SCNAction.group([spinAround, riseUp, fadeOut])
// 2
let gameOver = SCNAction.run { (node:SCNNode) -> Void in
    self.pigNode.position = SCNVector3(x:0, y:0, z:0)
    self.pigNode.opacity = 1.0
    self.startSplash()
}
// 3
triggerGameOver = SCNAction.sequence([goodByePig, gameOver])

```

Here's what happens in here:

1. This creates a few basic actions: one to spin the pig 720 degrees, one to move him up into the sky and another to fade him into nothingness. All three actions are put together under a single action group, fittingly named `goodByePig`. This is the animation sequence that sends poor Mr. Pig to heaven's gate when he meets his fate. :]
2. The `SCNAction.runAction(_)` class method creates a special action that allows you to inject code logic into an action, which then can be executed just like any other action. This specific code block simply resets Mr. Pig to his original position and opacity, and then triggers `startSplash()` to bring you back to the splash scene.
3. This creates the final `triggerGameOver` action sequence that first executes the `goodByePig` action. Once completed, it executes the `gameOver` run block action.

To finish off this chapter, add the following to the bottom of `stopGame()`:

```
pigNode.runAction(triggerGameOver)
```

This will ensure that whatever makes a call to the `stopGame()` function will trigger the `triggerGameOver` action sequence, ultimately ending the game. So sad... :[

To test this, add the following temporary code to the top of `handleGesture(_)`:

```

stopGame()
return

```

Build and run, start the game, then swipe in any direction to trigger the death animation. Poor pig!

Be sure to delete or comment out the test code before you continue:

```

//stopGame()
//return

```

Where to go from here?

Your stellar performance has brought you to the end of yet another chapter! Your game is in fantastic shape and there's not too much left to do. You can find the final build for this chapter under the **projects/final/Mr.Pig/** folder.

To recap what you've learned:

- **Actions:** You learned about actions and how to combine them to build intricate animation sequences.
- **Actions Editor:** You learned all about Xcode's built-in secondary editor for SCNNode, aka the actions editor.
- **Timing Functions:** You learned about timing functions that manipulate the progression of an action over time. It also allows you to simulate realism in action-packed animation sequences.
- **Coding Actions:** You also got your hands dirty by manually creating a whole bunch of different actions for your game in code.

There are a few things that are left for you to address, one of the most hilarious being that our hero is unstoppable — neither tree nor car nor bus can stop him. Did you mean to make some kind of mutant super-pig? :]

The next chapter will focus on solving that by means of collision detection.

Chapter 22: Advanced Collision Detection

Chris Language

Getting started

Your game is almost done. It has a vibrant splash scene complete with spinning sun rays, a twerking pig and a game scene that hosts a beautiful park filled with lovely trees, coins and two massive traffic-filled highways.

To top it off, you've added animations to bring the whole thing to life.

For this chapter, your goals are to solve a few problems:

- Nothing can block the little pig right now. Typically obstacles like the trees would fence him in. This poses a secondary challenge — you need to block movement proactively, so there isn't a way for the pig to collide with the tree.
- Traffic isn't a threat, which makes for a supremely unchallenging game. You'll change all that. The next time the little pig runs in front of a bus, it will be his last! :]
- Your poor little pig can only look at the pretty, shiny coins — he can't pick them up. Don't worry, because you'll solve that too.

Now that you know what needs to be done — wake up and smell the bacon. It's time to get to it!

Note: There's a starter project for you available under [projects/starter/Mr.Pig/](#), it continues exactly where the previous chapter left off.

Hidden geometry for collisions

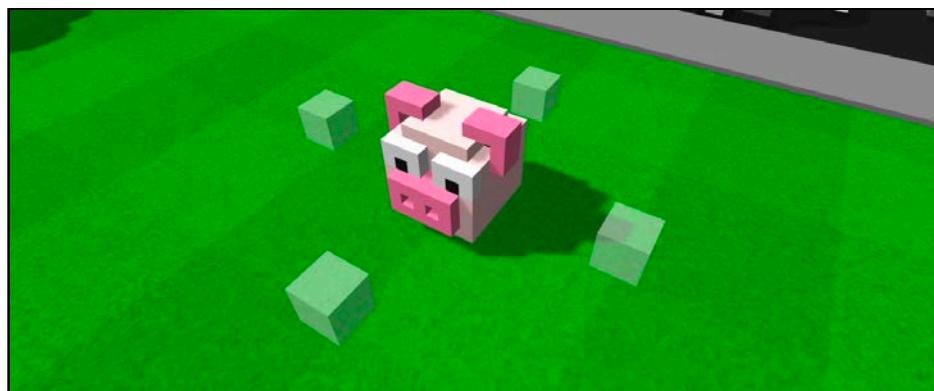
You've already covered basic collision detection and are familiar with collision masks and how they work. To proactively block the little pig's movement before he collides with an obstacle such as a tree, you'll use some ultra-cool, advanced collision detection techniques.

The secret is to make use of hidden geometry: it's geometry that's invisible yet still interacts with the physics system. It actually causes an active collision with nearby obstacles, essentially giving Mr. Pig a sixth sense.

He can only move one space forward, backward, left or right. By creating four boxes placed around the pig for each one of those directions, you'll be able to keep track of every potential collision in the pig's immediate vicinity.

You simply need to block jumps in the direction(s) where boxes are actively in a collision. Mind-blowing stuff, right?

In the below scenario, you can see four boxes placed around the pig. None are currently in an active collision. In this case, Mr. Pig can freely jump in any direction.



Now consider the next scenario. In this instance, the box to the right is currently in a collision with an obstacle. Now you have something substantive to use to prevent the pig from jumping to the right.

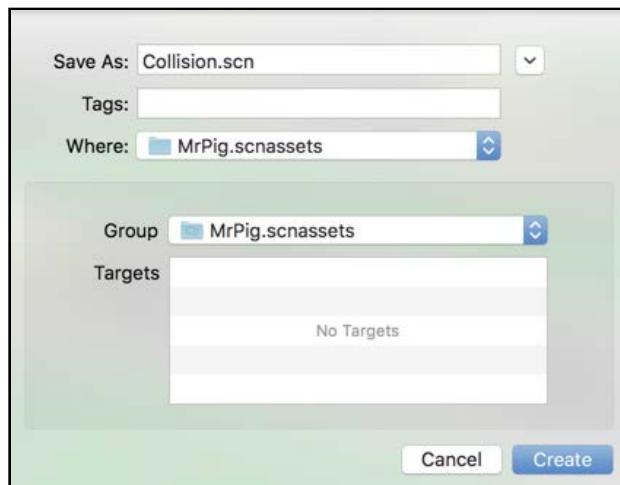


Create a hidden collision node

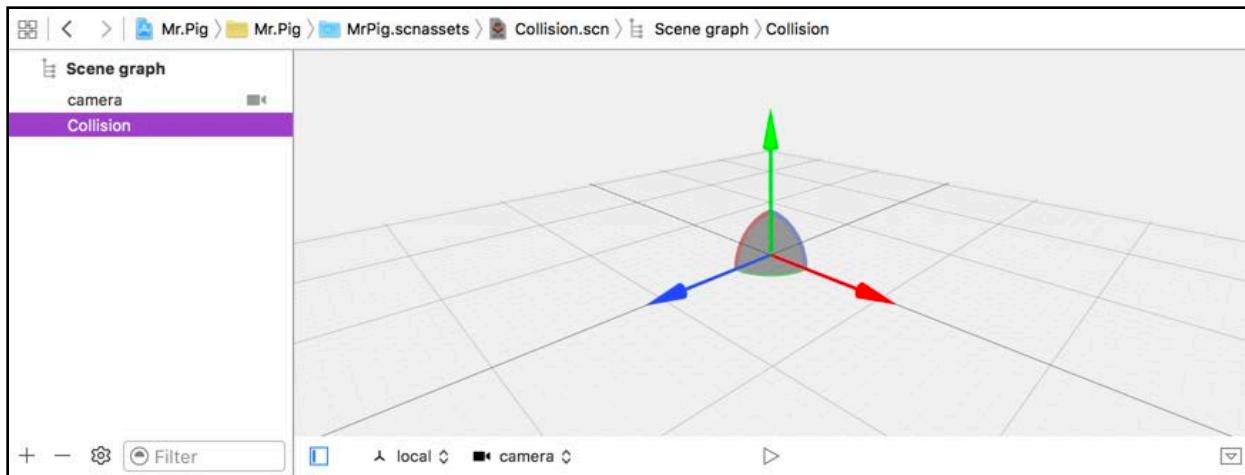
Now that you know how the hidden geometry collision technique will work, you need to create the collision node that'll contain the four boxes you'll use for the purpose of collision detection.

Creating a collision node

Create a new empty scene by dragging and dropping a **SceneKit Scene File** into the root of your project folder. In the creation wizard, name the new scene **Collision.scn**, and make sure you save it under **MrPig.scnassets**.

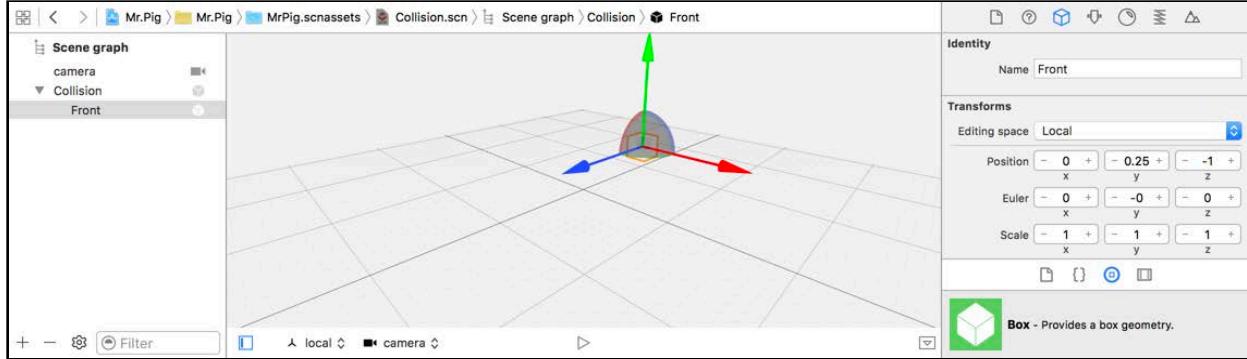


With **Collision.scn** selected, add an empty node to the scene graph and name it **Collision**.

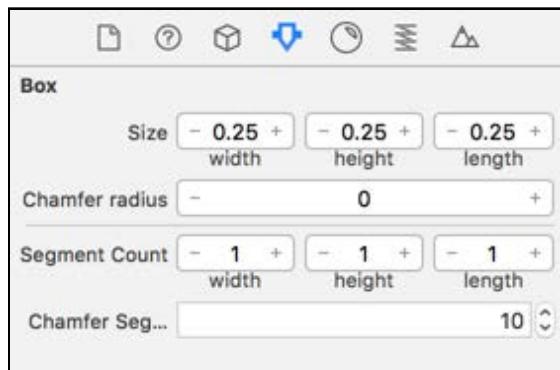


This will be the group node for the collision boxes. Now to create those boxes, drag and drop a **Box** into the scene, and make sure to place it under the **Collision** group node.

Name the box **Front** and position it at (x:0, y:0.25, z:-1) to offset it a bit from the center.

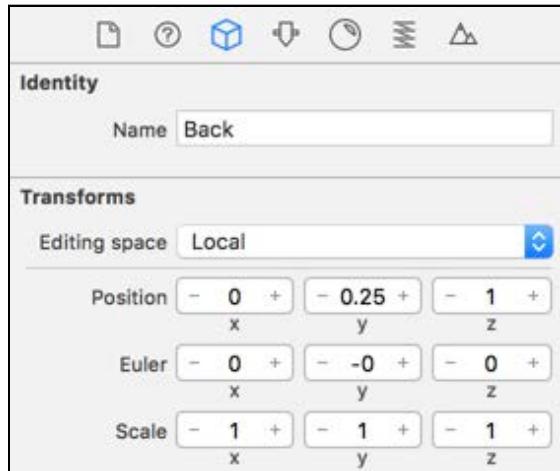


Bring up the Attributes Inspector and set the **size** to (x:0.25, y:0.25, z:0.25) — a bit smaller than the default.

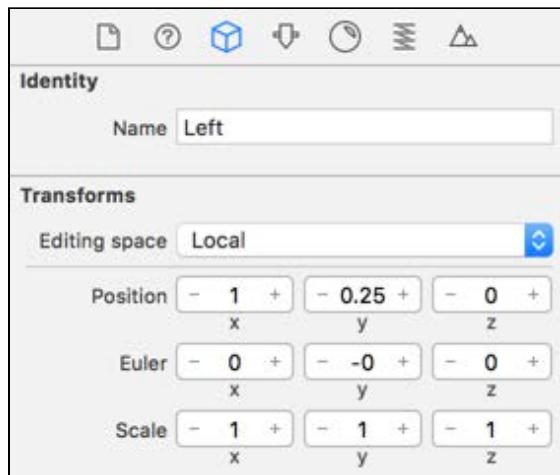


Now simply press **Option** and **Command** to drag out three copies of the front box for the back, left and right. Make sure that all the new copies are placed under the **Collision** group node, just like the front box node you created.

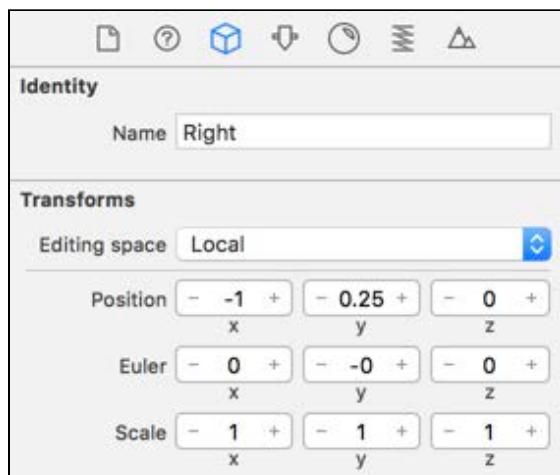
Once you have three copies of the node, you need to position them correctly. Start off with the back box. Name it **Back** and **position** it at (x:0, y:0.25, z:1).



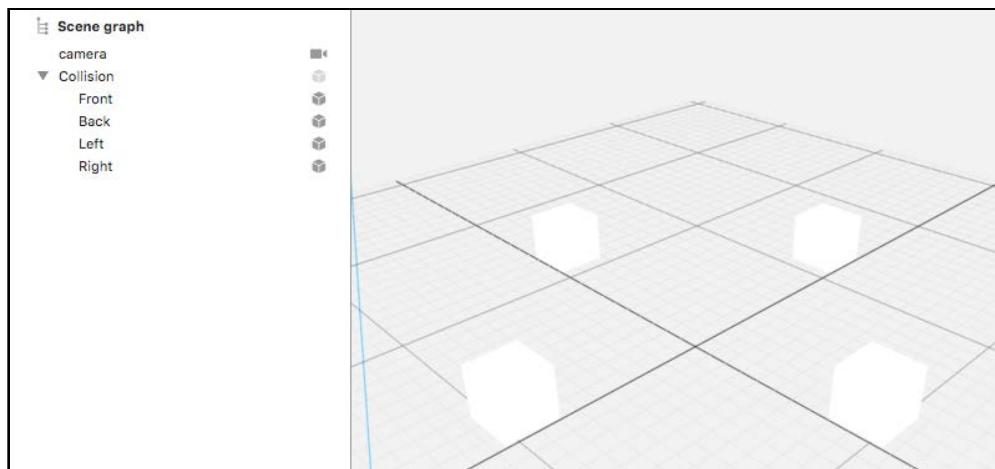
Next, select the node that will be your **Left** box. Name it **Left** and **position** it at $(x:-1, y:0.25, z:0)$.



Finally, select the remaining node, name it **Right** and **position** it at $(x:1, y:0.25, z:0)$.



At this point, your scene editor should look like this:



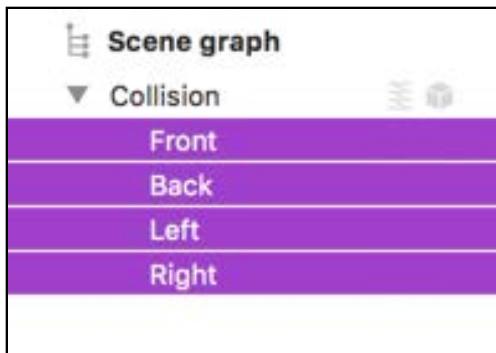
You're halfway done with this part and will play around with physics next.

Enabling physics

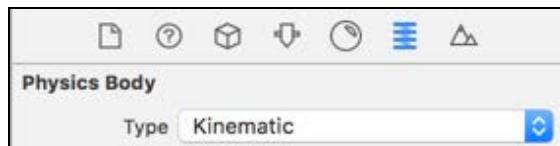
Each box needs a category bit mask so that you can tell which one is involved in a collision with an obstacle.

You're about to do a cool little trick that the scene editor allows you to do — accessing and editing multiple node's attributes and physics properties at the same time. Say what? :]

Start by selecting all the boxes. A quick way to do this is by selecting the first box in the scene graph, and then holding **Shift** while clicking the last box.



With all the nodes highlighted, bring up the Physics Inspector. Change the **Type** to **Kinematic**.



Since you've selected all four nodes, this change applies to all of the boxes.

Note: This cool little feature works for all the inspectors in the scene editor, so you can use the trick anytime you've got a group of nodes that should have similar properties — obviously, a box node will have different attributes than a sphere node.

Another thing to point out is that if all of the selected nodes have the same value for a specific property, then that value would be visible. If one of the selected nodes has a different value than the others, then you would see **Multiple Values** as a value. You can quickly synchronize properties by using this feature.

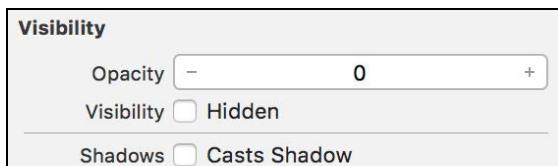
Here's another little trick to perform: Try licking your elbow! Just kidding, stop trying, it's impossible. Seriously, stop now! :]

The *actual* trick is to hide the geometry to conceal your clever little collision trick from the player.



Besides, it would look pretty silly if those four boxes showed during game play.

With the four box nodes still selected, select the Node Inspector then scroll down to the **Visibility** section. Set **Opacity** to **0.5**. You also need to disable shadows by unchecking **Casts Shadow**, so that the boxes don't give themselves away with shadows.



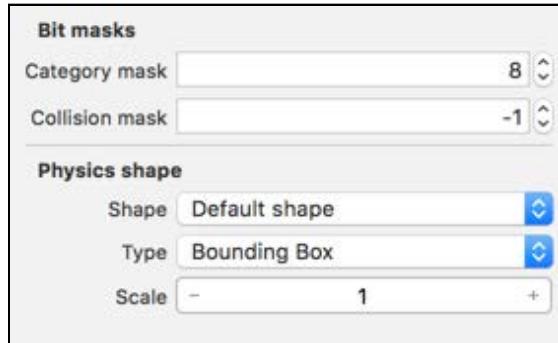
For your purposes, they shouldn't have an opacity of **0**, because it's helpful to see them in action while you build. In the final version of the game, you'll change the opacity to **0** to make the boxes invisible.

Note: By setting a node's opacity to **0**, the node is physically still in the scene, it's just invisible. This means that if you have physics properties set on that node, it will still participate in collisions during the physics simulation.

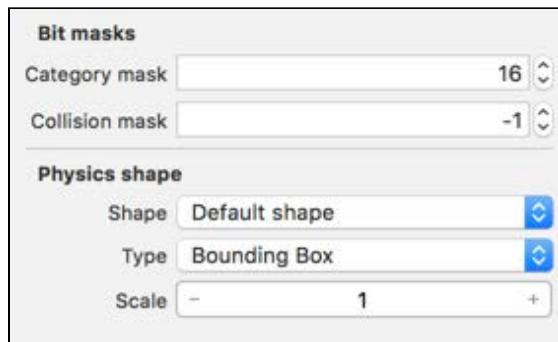
If you were to set the node's visibility to **Hidden**, you'd completely remove the node from the scene to such a point that it wouldn't cause any collisions even if it had physics properties.

Things are about to get more granular.

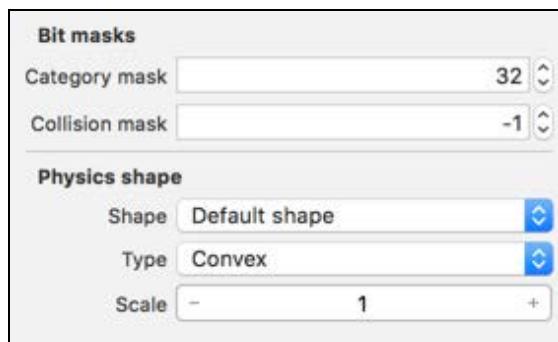
You need to go to each box individually to set up category bit masks because each will have different values. Start with **Front**, bring up the Physics Inspector and set its **Category mask** to **8**.



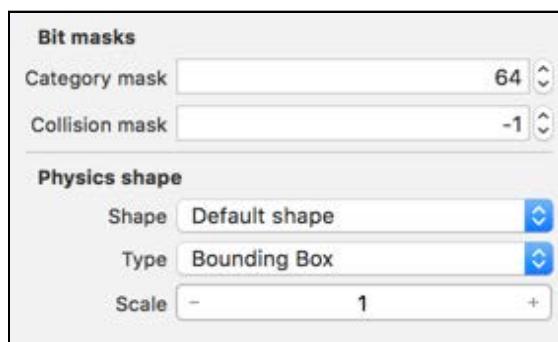
For **Back**, set its **Category mask** to 16.



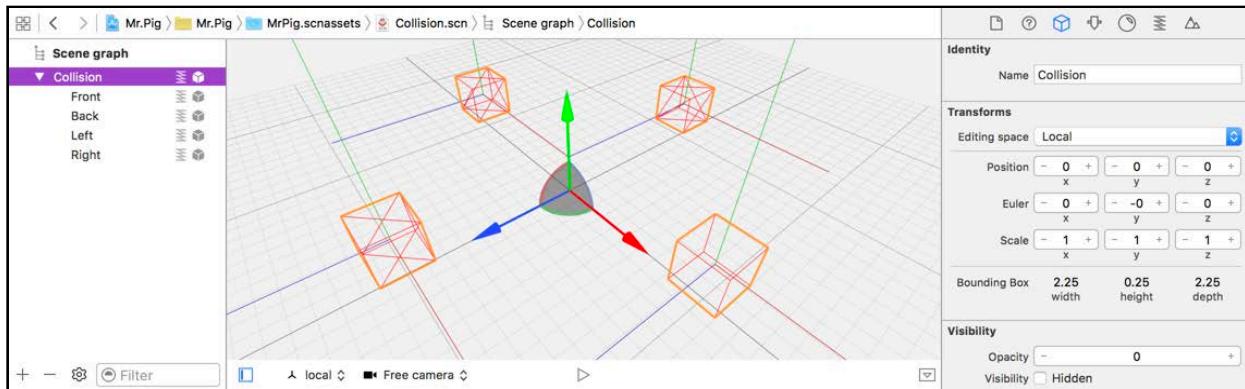
Now for **Left**, set its **Category mask** to 32.



Then finally, set **Right** to have a **Category mask** to 64.



Remember to delete that default **camera**. After that, you're all done!



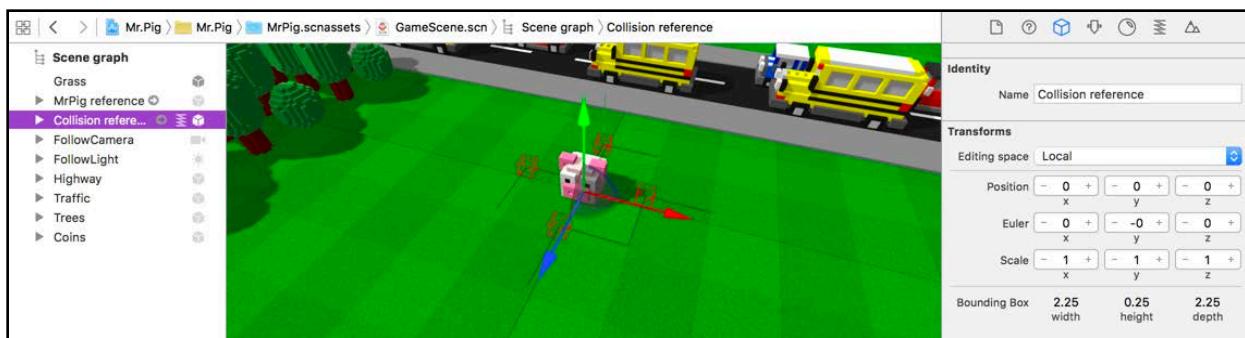
You should now have a **Collision.scn** with four little boxes placed nicely around the middle point of the scene.

Use the collision node

With **Collision.scn** created, what's left is to use this node as a reference node in your game scene.

Adding the collision reference node

Select **MrPig scnassets/GameScene.scn**, then drag and drop a **Collision.scn** reference node into the scene.



Be sure to position it exactly at position (x:0, y:0, z:0), smack bang on the pig.

Now you need to attach your code to the nodes. Add the following properties to **ViewController** in **ViewController.swift**:

```
var collisionNode: SCNNNode!
var frontCollisionNode: SCNNNode!
var backCollisionNode: SCNNNode!
var leftCollisionNode: SCNNNode!
var rightCollisionNode: SCNNNode!
```

These are the properties you'll use to access the **Collision** group node, as well as each collision box node: **Front, Back, Left and Right**.

To bind the code to the nodes in the scene, add the following to the bottom of `setupNodes()`:

```
collisionNode = gameScene.rootNode.childNode(withName: "Collision",
recursively: true)!
frontCollisionNode = gameScene.rootNode.childNode(withName: "Front",
recursively: true)!
backCollisionNode = gameScene.rootNode.childNode(withName: "Back",
recursively: true)!
leftCollisionNode = gameScene.rootNode.childNode(withName: "Left",
recursively: true)!
rightCollisionNode = gameScene.rootNode.childNode(withName: "Right",
recursively: true)!
```

This will bind all the different properties to the **Collision** group node and each collision box node.

Create the render loop

This collision node has to follow Mr. Pig around. The simplest way to do that is to make the position of the collision node the same as the pig inside the render loop updates.

First, you need to create a new method that will be responsible for updating the node's positions during the render loop of the game. Add the following method to `ViewController`:

```
func updatePositions() {
    collisionNode.position = pigNode.position
}
```

This will keep the position for `collisionNode` in sync with the position for `pigNode`.

Now that you have this method in place, you need to call it in your game's render loop. To do that, you're going to implement the `renderer(_:`
`didApplyAnimationsAtTime:)` delegate method from the `SCNSceneRendererDelegate` protocol.

Add the following to the bottom of **ViewController.swift**:

```
// 1
extension ViewController : SCNSceneRendererDelegate {
// 2
    func renderer(_ renderer: SCNSceneRenderer, didApplyAnimationsAtTime:
time:
TimeInterval) {
// 3
    guard game.state == .playing else {
        return
    }
// 4
```

```
    game.updateHUD()
    // 5
    updatePositions()
}
```

Take a closer look at that code:

1. This ensures that `ViewController` conforms to the `SCNSceneRenderDelegate` protocol. You use a class extension to organize code to satisfy the protocol so that it's separate from the rest of your `ViewController` code.
2. This injects your update game logic just after all the animation actions have completed inside the render loop. This way you know the exact position of each object in your scene, both after the applied actions and before the next pass through the render loop.
3. Again, keeping game states in mind, you only want to do updates while the game is in a `.playing` state. This guard statement will prevent the rest of the method from running if `game.state` is not `.playing`.
4. This ensures that the HUD node gets updated after any render updates. You added the HUD as a child node to `cameraNode` in a previous chapter.
5. Finally, you make a call to `updatePositions()`, keeping the `collisionNode` position in sync with the `pigNode` position.

Remember to set `ViewController` as the delegate for the view by adding the following line of code to the bottom of the `setupScenes()`:

```
scnView.delegate = self
```

Do a quick build and run and move the pig around to verify the render loop is actually functional.



If you used an opacity of `0.5` for the boxes, you should see the four boxes follow Mr. Pig everywhere he goes, like his personal security detail. You should also notice the updates that happen in the HUD at the top of the screen. Excellent!

Note: Quick clarification of the contents of the HUD: The pig snout shows the total amount of coins collected, and the little house shows the total number of coins banked.

Add physics

Defining bit masks

Continuing on through some more grueling, granular tasks, you'll define a bunch of collision masks next. In `ViewController`, define the following constants:

```
// 1
let BitMaskPig = 1
let BitMaskVehicle = 2
let BitMaskObstacle = 4
let BitMaskFront = 8
let BitMaskBack = 16
let BitMaskLeft = 32
let BitMaskRight = 64
let BitMaskCoin = 128
let BitMaskHouse = 256
```

Now you have a good idea of all the elements in the game that will play an important role within the collision detection space.

Enabling physics

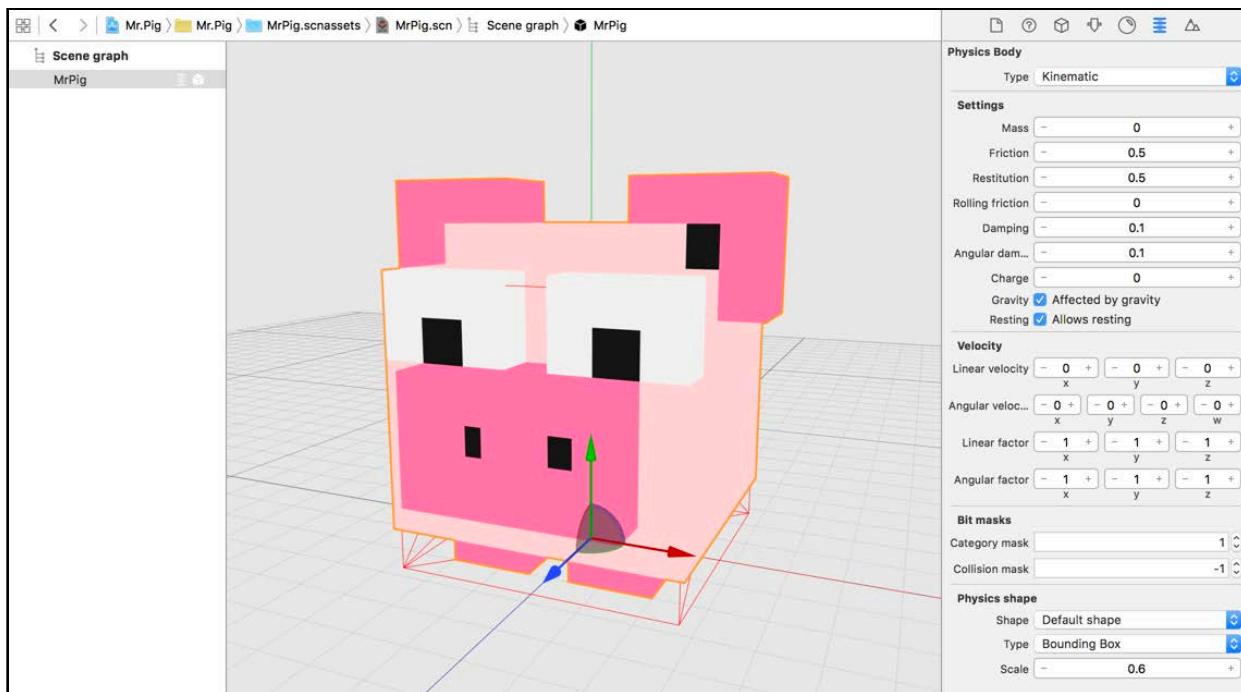
Now that the bit mask constants are defined, you get to move on to a fun little exercise where you'll enable physics for all the important elements of your game, starting with the *most important* element, our hero, Mr. Pig.

Select **MrPig.scnassets/MrPig scn** to open up the reference node for Mr. Pig.

Select the **MrPig** node in the scene graph and open up the Physics Inspector.

Change **Type** to **Kinematic** because you'll be running actions on the pig node to change its position.

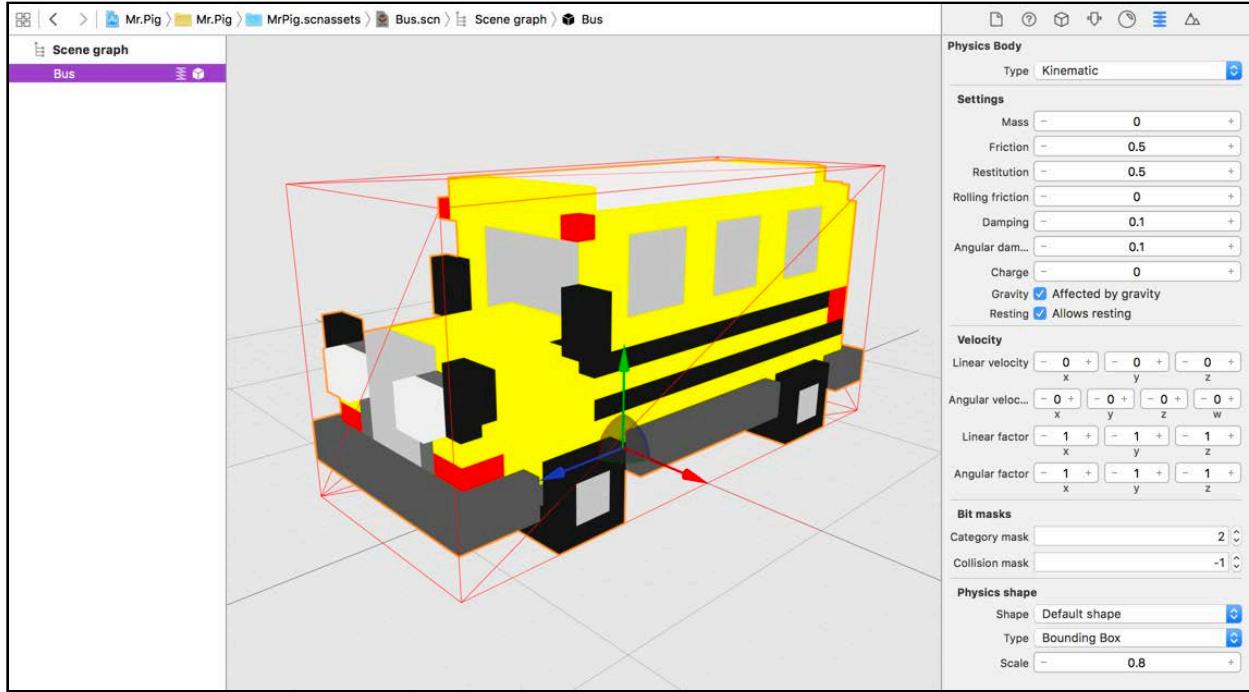
Under the **Bit masks** section, change **Category mask** to 1. Then finally, under the **Physics shape** section, change **Type** to **Bounding Box** and set **Scale** to 0.6 to shrink the bounding box down to a smaller size.



Note: When your game reaches its final stages, you might want to come back and tweak the bounding box size to give the collisions a bit of leeway.

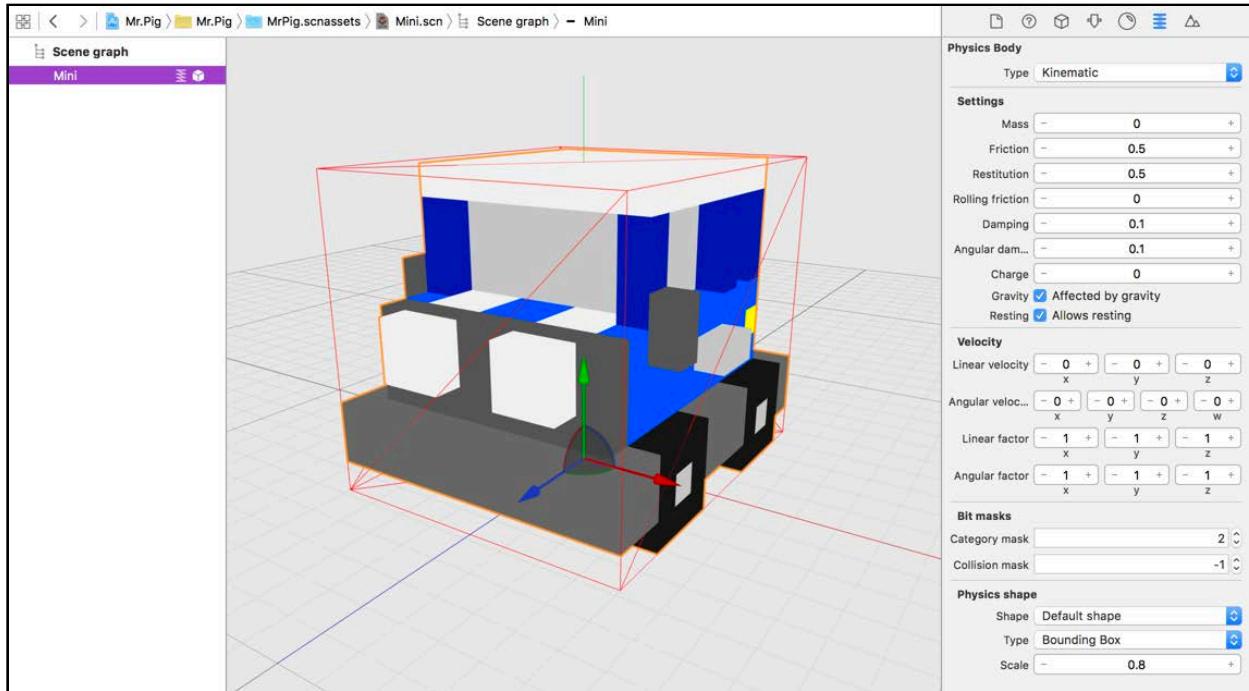
Vehicles are up next, so select **MrPig.scnassets/Bus scn** and follow the same process as before. Select the **Bus** node in the scene graph and open the Physics Inspector. Remember you already have a move action running on the bus node, so you have to change the **Type** to **Kinematic**.

Next, change the **Category mask** to 2, which is the same bit mask you'll use for all the vehicles. Then finish off by scrolling down to **Physics shape** and setting **Type** to **Bounding Box** and **Scale** to 0.8:



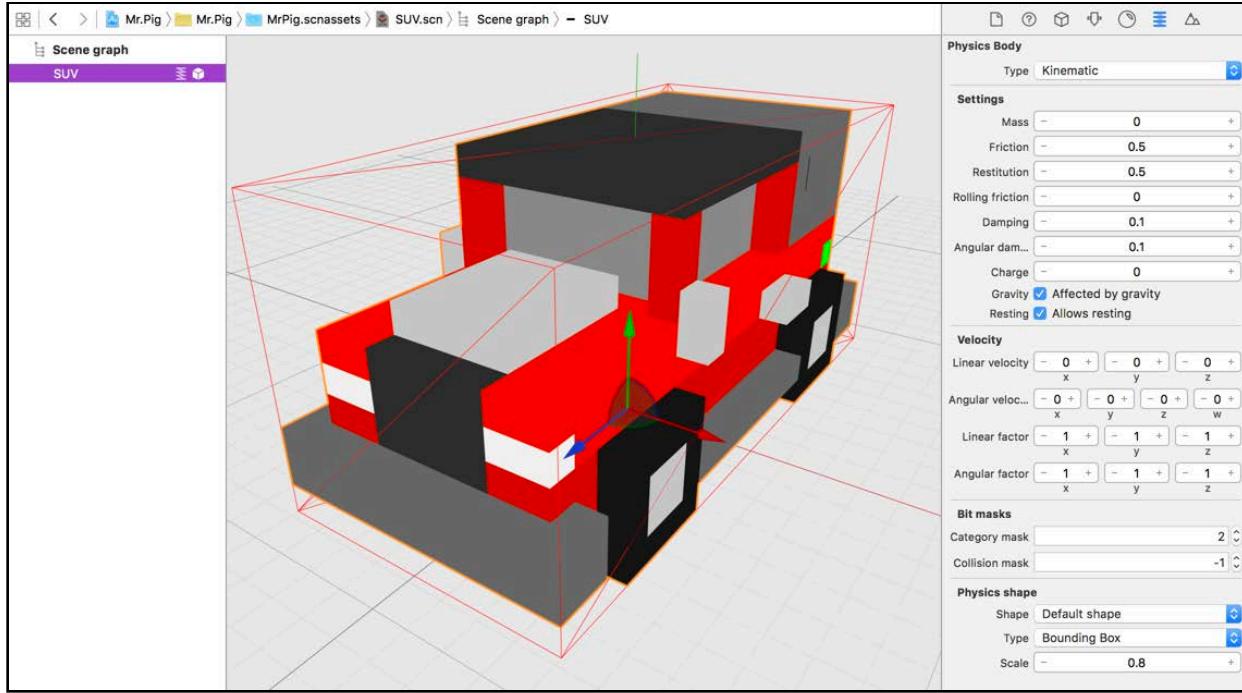
Next in line is **MrPig.scnassets/Mini.scn**. Again, with the **Mini** node selected, set **Type** to **Kinematic** in the Physics Inspector then set the **Category mask** to 2.

Finally, under **Physics Shape**, set the **Type** to **Bounding Box** with a **Scale** of 0.8:



Select the last vehicle, **MrPig.scnassets/SUV.scn**. The SUV will be exactly like the Bus and Mini, so select the **SUV** node and open the Physics Inspector. Set the **Type** to **Kinematic**, then set the **Category mask** to 2.

Finally, under **Physics shape**, set **Type** to **Bounding Box** and **Scale** to 0.8:

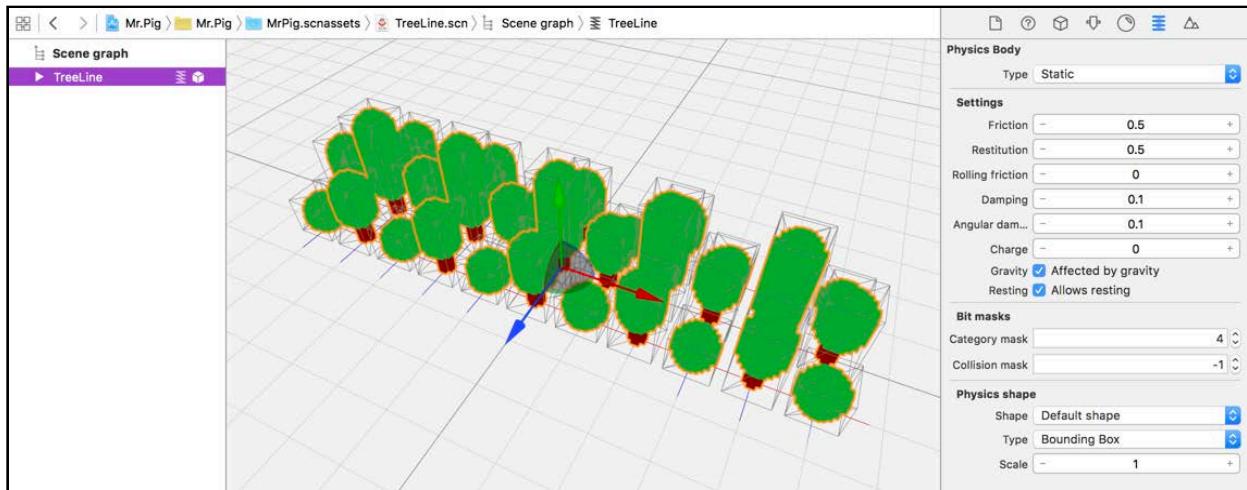


Let's see. Pig? Check. Vehicles? Check. Trees? Not set up yet.

To keep you on your toes, instead of enabling physics on each tree, you're going to enable physics on the reference nodes you created in an earlier chapter, **MrPig.scnassets/TreeLine scn** and **MrPig.scnassets/TreePatch scn**.

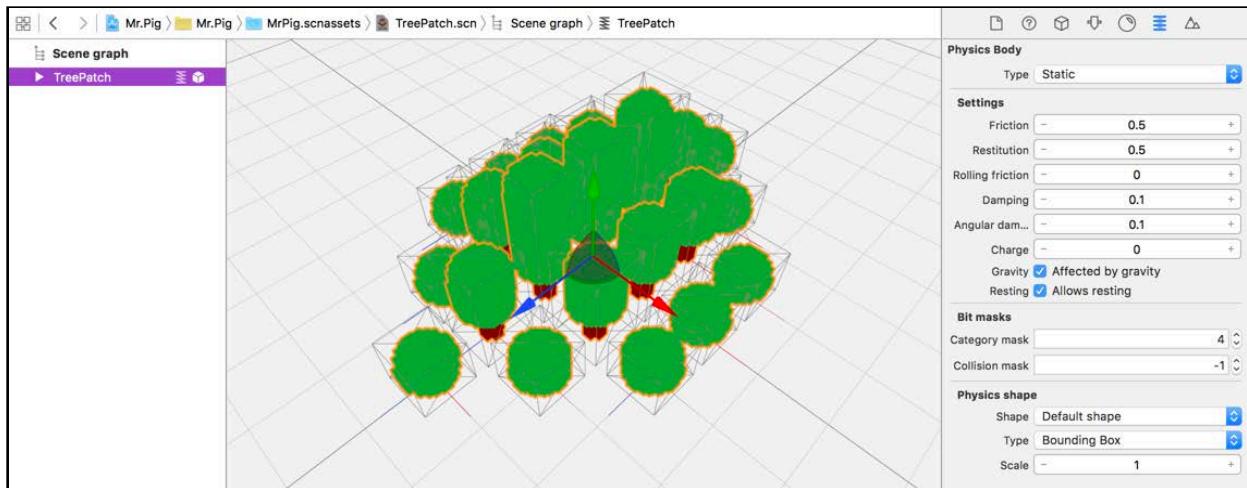
First, select **MrPig.scnassets/TreeLine scn**. Make sure you have the **TreeLine** node selected and the Physics Inspector opened. Trees don't need to move around — unless you're planning to create some kind of fantasy world — so you're going to set the **Type** to **Static**.

Set the **Category mask** to 4, indicating that the trees are all obstacles. Under **Physics shape**, set **Type** to **Bounding Box** and leave the **Scale** at 1.



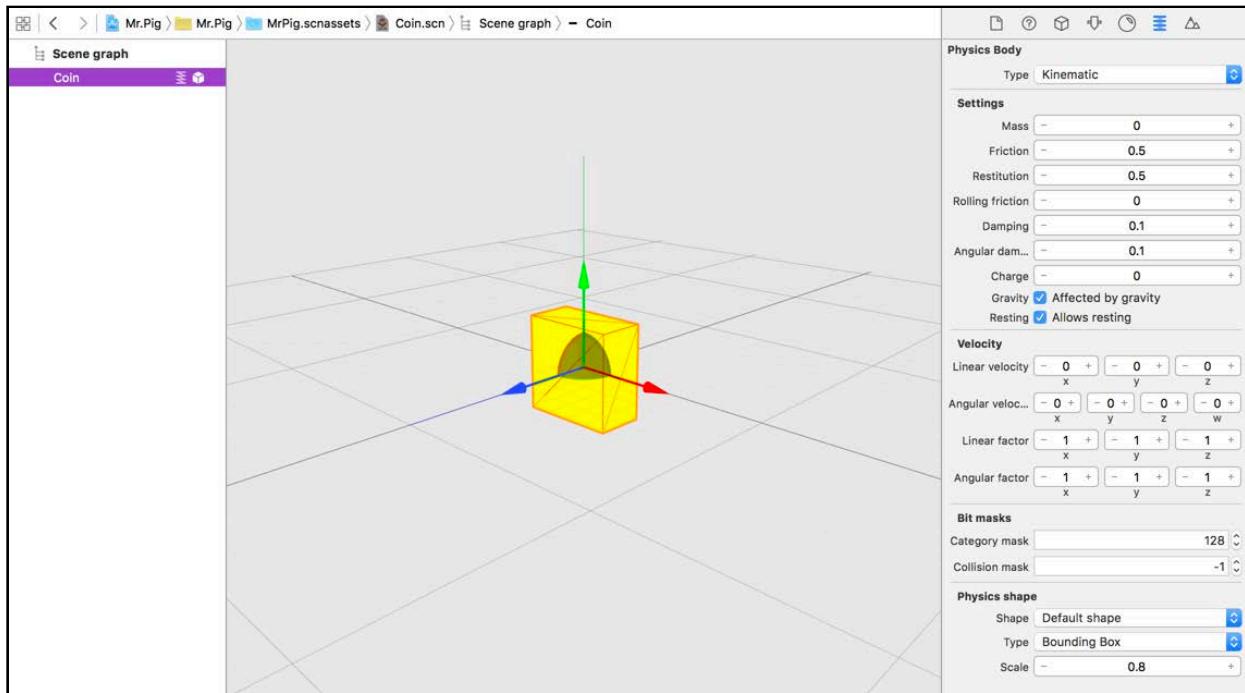
Because the **TreeLine** node consists of several child tree nodes, you're saving yourself a ton of work once again. The children will inherit the parent's physics properties, saving you from enabling physics on each and every little tree.

Select **MrPig.scnassets/TreePatch.scn** next. This one will work exactly the same as the **TreeLine** node. With the **TreePatch** node selected, open the Physics Inspector and set the **Type** to **Static**, **Category mask** to 4. Under **Physics shape**, set the **Type** to **Bounding Box** and leave the **Scale** at 1:



It looks like you're just down to playing around with the coins. Find the **MrPig.scnassets/Coin.scn** reference node.

As it was before, actions are running on the coin, so you need to set the **Type** to **Kinematic**. Set the **Category mask** to 128, then change the **Type** under **Physics shape** to **Bounding Box** with a **Scale** of 0.8.



You're finally all done with that. Phew! :]

Setting contact bit masks

Now you're back to one of your original objectives: actually blocking the pig from colliding with other objects. For this, you'll make use of the contact test between physics bodies that lets you know when two bodies touch.

You can set the **Contact Mask** in SceneKit editor, but you can also manually set that up in code. Fortunately, you don't have to figure it all out on your own!

The following snippet of code has you covered — just open up **ViewController.swift**, add this to the bottom of `setupNodes()` and you're all set:

```
// 1
pigNode.physicsBody?.contactTestBitMask = BitMaskVehicle | BitMaskCoin |
BitMaskHouse
// 2
frontCollisionNode.physicsBody?.contactTestBitMask = BitMaskObstacle
backCollisionNode.physicsBody?.contactTestBitMask = BitMaskObstacle
leftCollisionNode.physicsBody?.contactTestBitMask = BitMaskObstacle
rightCollisionNode.physicsBody?.contactTestBitMask = BitMaskObstacle
```

There are a couple of things to note:

1. This sets up the contact test bit mask for `pigNode`. From this, you now know the pig itself will be able to make contact with vehicles, coins and the house.
2. This sets up the contact test bit mask for all the box nodes inside the **Collision** node. The boxes are interested in any object that's an obstacle.

Handle collisions

Collisions with obstacles

As you learned in Chapter 10, “Basic Collision Detection”, you set the `contactTestBitMask` of a physics body to send a notification whenever it touches another physics body with category mask that matches the mask value.

To keep track of the active collisions in your game, you’ll create a special property named `activeCollisionsBitMask`. When one of the four collision boxes makes contact with an obstacle, the `physicsWorld(_:didBegin:)` delegate method will be triggered.

You can then use the affected box’s category bit mask and add it to the `activeCollisionsBitMask` by means of a bitwise OR (`|`) operation. This essentially keeps track of all active collisions. Then, the gesture handler can inspect `activeCollisionsBitMask` and ultimately block the gestures based on the active collision directions.

Once the collision ends, the `physicsWorld(_:didEnd:)` delegate method will be triggered. At that point, you can remove the affected box’s category bit mask from `activeCollisionsBitMask`.

This is done by means of first performing a bitwise NOT (`~`) operation on the category bit mask and then performing a bitwise AND (`&`) on the result.

Add the following property to `ViewController`:

```
var activeCollisionsBitMask: Int = 0
```

This is the bit mask that will keep track of all active collisions. Now you need to implement the methods from the `SCNPhysicsContactDelegate` protocol. Add the following code to the bottom of **ViewController.swift**:

```
// 1
extension ViewController : SCNPhysicsContactDelegate {
// 2
    func physicsWorld(_ world: SCNPhysicsWorld,
                      didBegin contact: SCNPhysicsContact) {
// 3
        guard game.state == .playing else {
            return
        }
// 4
        var collisionBoxNode: SCNNNode!
        if contact.nodeA.physicsBody?.categoryBitMask == BitMaskObstacle {
            collisionBoxNode = contact.nodeB
        } else {
            collisionBoxNode = contact.nodeA
        }
// 5
```

```
    activeCollisionsBitMask |=
        collisionBoxNode.physicsBody!.categoryBitMask
    }
    // 6
    func physicsWorld(_ world: SCNPhysicsWorld,
        didEnd contact: SCNPhysicsContact) {
        // 7
        guard game.state == .playing else {
            return
        }
        // 8
        var collisionBoxNode: SCNNode!
        if contact.nodeA.physicsBody?.categoryBitMask == BitMaskObstacle {
            collisionBoxNode = contact.nodeB
        } else {
            collisionBoxNode = contact.nodeA
        }
        // 9
        activeCollisionsBitMask &=
            ~collisionBoxNode.physicsBody!.categoryBitMask
    }
}
```

Here's a section-by-section breakdown:

1. This adds a class extension to `ViewController` and makes the class conform to the `SCNPhysicsContactDelegate` protocol.
2. This defines a handler for when a `physicsWorld(_:didBegin:)` event gets triggered.
3. You only want to keep track of collisions while the game is in a `.playing` state.
4. This familiar bit of code is where you determine whether `nodeA` or `nodeB` is the obstacle, which means that the other node is the collision box.
5. This does a bitwise OR operation to add the colliding box's category bit mask to `activeCollisionsBitMask`.
6. This defines a handler for when a `physicsWorld(_:didEnd:)` event gets triggered.
7. Again, you only want to keep track of these events while the game is in a `.playing` state.
8. Again, this is used to determine which node in the contact test is the collision box.
9. Finally, this does a bitwise NOT operation followed by a bitwise AND operation to remove the collision box category bit mask from the `activeCollisionsBitMask`.

Now you're ready for code that'll inspect the `activeCollisionsBitMask` to block gestures inside the gesture handler.

Add the following inside `handleGestures(_:)` right after the guard, making sure you're in a `.playing` state:

```
// 1
let activeFrontCollision = activeCollisionsBitMask & BitMaskFront ==
BitMaskFront
let activeBackCollision = activeCollisionsBitMask & BitMaskBack ==
BitMaskBack
let activeLeftCollision = activeCollisionsBitMask & BitMaskLeft ==
BitMaskLeft
let activeRightCollision = activeCollisionsBitMask & BitMaskRight ==
BitMaskRight

// 2
guard (sender.direction == .up && !activeFrontCollision) ||
(sender.direction == .down && !activeBackCollision) ||
(sender.direction == .left && !activeLeftCollision) ||
(sender.direction == .right && !activeRightCollision) else {
    return
}
```

Take a look at the code you just added:

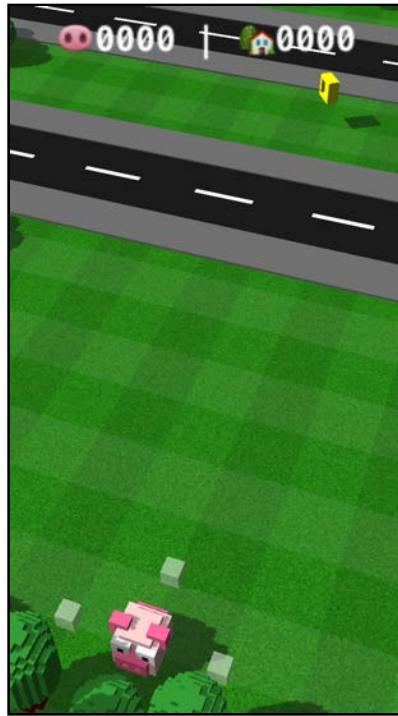
1. This uses a bitwise AND to check for active collisions in each direction stored in `activeCollisionsBitMask` and saves them in individual constants.
2. This guard statement makes sure that you only continue on to the rest of the gesture handler code when there is no active collision in the direction of the gesture. For example, if the gesture direction is up and there is an active collision, the entire condition will evaluate to false. Then the code execution will go to the `else` clause of the guard statement to end the gesture handler.

One last thing you need to do is to set up your `ViewController` as the contact delegate for your game scene's physics world by adding the following line of code to the bottom of `setupScenes()`:

```
gameScene.physicsWorld.contactDelegate = self
```

This sets `self` as the `contactDelegate` for `gameScene.physicsWorld`.

Time for a quick build and run to test things out.



Try and jump as far down as possible. If all sanity is intact, then Mr. Pig will not be able to jump into the tree anymore. Yay!

Collisions with vehicles

The next bit is easy. You need to make sure Mr. Pig doesn't survive when he throws himself in front of a bus.

Add the following code to the bottom of `physicsWorld(_:didBegin:)`:

```
// 1
var contactNode: SCNNode!
if contact.nodeA.physicsBody?.categoryBitMask == BitMaskPig {
    contactNode = contact.nodeB
} else {
    contactNode = contact.nodeA
}

// 2
if contactNode.physicsBody?.categoryBitMask == BitMaskVehicle {
    stopGame()
}
```

1. You should now be very familiar with how this snippet of code determines which node is the pig and which is not. Once done, you know for a fact that the `contactNode` is not the pig.
2. If the node the pig made contact with is indeed a vehicle, then it's the end of the game.

Build, run and throw that pig under a bus!



If you're fast enough, you can catch some traffic. Once the bus collides with the poor little pig, he flies off to heaven and the game transitions back to the splash scene, exactly as it was designed to do.

Collisions with coins

Next up, Mr. Pig needs to actually be able to collect those coins.

Add the following code to the bottom of `physicsWorld(_:didBegin:)`:

```
// 1
if contactNode.physicsBody?.categoryBitMask == BitMaskCoin {
    // 2
    contactNode.isHidden = true
    contactNode.runAction(SCNAction.waitForDurationThenRunBlock(duration:
        60) { (node: SCNNode!) -> Void in
        node.isHidden = false
    })
    // 3
    game.collectCoin()
}
```

Take a look at the code:

1. You check if the node the pig made contact with is a coin.
2. If it is, you hide the coin node, then run an action on it that will unhide the coin after 60 seconds.

3. Then you call the `collectCoin()` method on game, which will update the score.

Build and run and grab that coin!

Be careful though — Mr. Pig is a mere mortal now. Watch out for that bus! :]



If you manage to cross the road, you'll see coins disappear once Mr. Pig jumps on them. You should notice the score increase as well. Excellent!

Where to go from here?

You conquered the hardest tasks of your game, and the end is in sight! Reaching this point means you deserve a pat on the back. As always, you can find the final project under **projects/final/Mr.Pig/**.

You can continue with back-patting yourself — I can't reach through this page and do it, sorry; feel free to sneak in another attempt to lick your elbow while you're at it. :]

Understanding how to use hidden geometry to assist your game with collision detection is *the* take away from this chapter.

It's a technique you can apply to many use cases, including these:

- In an FPS game, it can be used to determine if your hero was stabbed from the front or back.

- In a platform game, it can be used to flip a nearby switch or check if your hero is standing close to the edge.
- You can also use hidden geometry for particle systems; for example, responding appropriately when someone steps in a campfire.

There are quite a few bits left unattended, so in the next chapter, you'll add those much-needed finishing touches. For now, go take a break to clear your head (and possibly lick your elbow), but hurry back!

23

Chapter 23: Audio

Chris Language

Getting started

Welcome to the last chapter about the 3D SceneKit game you've been building since Chapter 19 — Mr. Pig. Don't worry, that light at the end of the tunnel isn't a bus about to hit you, it's success barreling down on you!

The primary focus of this chapter is audio in SceneKit. Along the way, you'll put some final touches on the game and close up some pesky loose ends.

Note: There's a starter project for you available under [projects/starter/](#) [Mr.Pig/](#), it continues where the previous chapter ended.

There's one small difference: The opacity of the collision boxes is now set to 0 to make them completely invisible to the player. If you want to continue with *your* project, just make that same change before continuing.

Add finishing touches

Mr. Pig's habit of jumping out of the camera view is pretty annoying, and what kind of particle vacuum is eating all that traffic?

Don't worry. You're about to resolve these little annoyances by perfecting the game's render loops.

Update the camera's position

It's time to unleash Big Brother and follow that little pig's every move. Surely the authorities are wondering where on earth he gets all his money, and you need to keep a sharp eye on him so you can usher him and his coins safely across traffic.

Killing off that static camera is the best thing for all parties involved.

Open up **ViewController.swift** and add the following code to the bottom of `updatePositions()`:

```
let lerpX = (pigNode.position.x - cameraFollowNode.position.x) * 0.05
let lerpZ = (pigNode.position.z - cameraFollowNode.position.z) * 0.05
cameraFollowNode.position.x += lerpX
cameraFollowNode.position.z += lerpZ
```

In the previous chapter, you already created the `updatePositions()` method, which gets called 60 times per second as part of your game's render loop update.

In this addition, the first two lines calculate a linearly interpolated x and z value between `pigNode` and `cameraFollowNode`, with a factor of `0.05`. The results are then added to the position of `cameraFollowNode`. In turn, this moves the camera towards the pig's position over a period of time.

Instead of simply updating `cameraFollowNode` to the same position as that of the `pigNode`, this technique creates a smooth, lazy camera tracking effect.

Note: To make the camera less lazy and more responsive, you can tweak the factor. Setting the factor to `1.0` increases the camera tracking to 100 percent real-time.

Do a build and run and see if you can get the little pig to escape the eye in the sky.



At last, the camera follows the pig everywhere, and now he can explore the entire park under your watchful eye. Hey, did Mr. Pig just discover another coin?

Awesome! :]

Hang on — did you notice something odd about the scene?

Is that large shadow on the top-right an alien mothership about to land? And why the heck does that coin have no shadow? Is it impervious to sunlight?

Relax, there are no aliens in this game, and the shadow mystery has a rather logical explanation.

Update the light's position

In order to make your game as efficient as possible, one of the techniques you employed was tweaking light settings so that only the objects in view cast shadows. And that little tweak is the culprit for all those weird things.

More specifically, it's the result of the shadow clipping range on the directional light. Now that you know the problem, the fix is elementary: just make the light follow the camera around.

Add the following line to the bottom of `updatePositions()`:

```
lightFollowNode.position = cameraFollowNode.position
```

This code updates the position for `lightFollowNode` to be the same as `cameraFollowNode`, thus keeping the light in sync with the camera's point of view.

Do another build and run to see if the shadow issue is resolved.



Hey, that coin has a shadow! It looks like you successfully foiled the alien invasion too.

What a lovely, sunny day indeed!

Update traffic bounds

On to your next problem — where is all that traffic going? Something is seriously wrong here; traffic never just disappears. :]

What you want to accomplish is the effect of endless traffic by only using a few cars. Fortunately, the solution is quite simple — you'll implement a bounds check and a position reset.

By introducing a bounds check for each moving vehicle, you can actively detect when each one drives past a defined boundary, and then set the position back to the opposite side of the scene.

The vehicle has to travel from the beginning again, thus driving through the scene in an endless loop of madness.

Add the following `updateTraffic()` method to `ViewController`:

```
func updateTraffic() {  
    // 1  
    for node in trafficNode.childNodes {  
        // 2  
        if node.position.x > 25 {  
            node.position.x = -25  
        } else if node.position.x < -25 {  
            node.position.x = 25  
        }  
    }  
}
```

1. You are iterating through all the vehicle nodes placed under `trafficNode` group node.
2. Once the node's x-position crosses the 25 unit mark, you reset it to -25 and vice versa for nodes moving in the opposite direction.

Don't forget to actually call the `updateTraffic()` method inside the render loop update. Add the following code to the bottom of `renderer(_:_didApplyAnimationsAtTime:)`:

```
updateTraffic()
```

Build and run and review the changes.



Wow, the traffic flows forever and ever, just like in real life! :] How on earth did the poor little pig manage to get himself trapped between the highways?

Challenge

Why did the little pig cross the road? Because he got *boared!* Ahem...the real answer is because he wanted to *score* points.

Speaking of scoring, it's time to reward yourself by proving you've got the skills to crack this challenge. What? Huh?

That's right, it's challenge time, and this one is specifically designed to give your game some purpose.

Consider this: What happens if Mr. Pig runs across the road but stays in the park, never to cross the road again? He's a smart little pig. He would totally try to do something like that just to avoid a run-in with an SUV.

However, there's an incentive to make that dangerous trek across the highway: *points*. In order to score, the little pig has to bank those coins.

You might recall that Mr. Pig banks coins in his house (most likely under the mattress) and that he's got a kettle of tea on the ready.

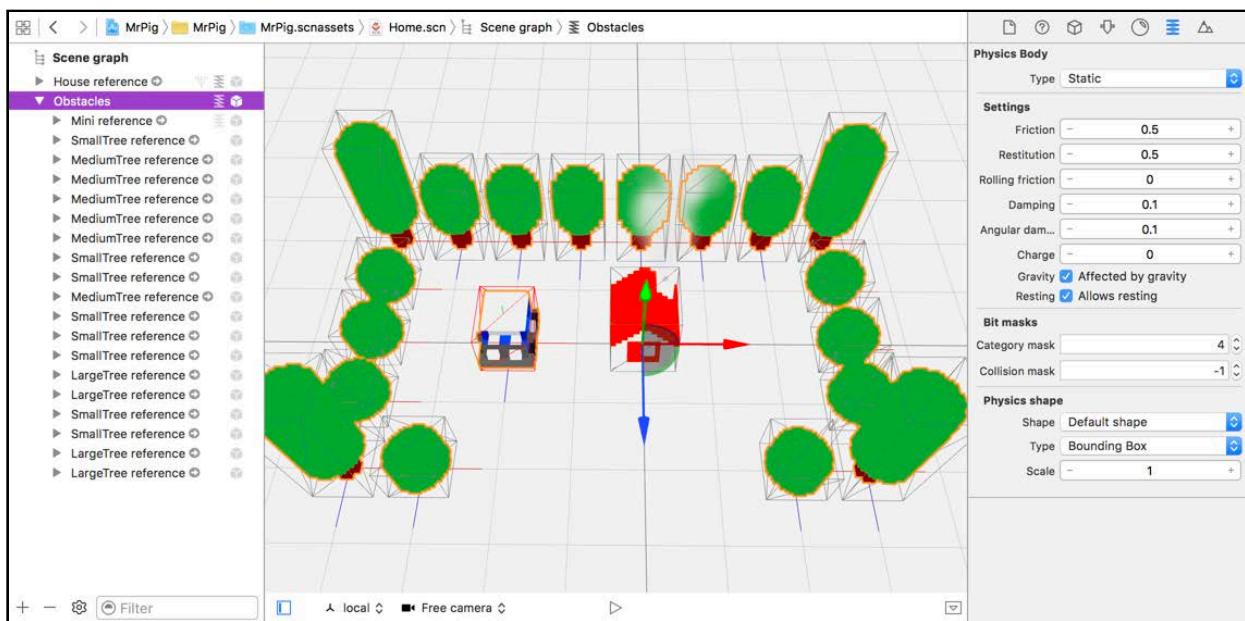
Your challenge, dear reader, is to build that home.

Fear not, most of the hard work is done, and you won't have to pick up a hammer. All you need to do is build a small reference scene with a little house, car and garden in it. Doesn't that sound like fun?

Here's a high-level look at the steps ahead:

1. Start by creating an empty SceneKit scene named **Home.scn** and deleting the default camera.
2. Add a little **House.scn** into the scene, right in the middle.
3. Create an empty group node named **Obstacles**. Make sure you place all the rest of the objects for this scene under this node.
4. Add a few trees — big, medium and small.
5. Add a little **Mini.scn** too.

You can use the following reference image for building Mr. Pig's little **Home.scn**:



7. You need to set up the physics for all **Obstacles** too; make sure they are static physics bodies with a category bit mask of 4. For the little **House**, use a category bit mask of 256. Remember to change their physics shapes to a bounding box as well.
8. Once you're done with the scene, just add a reference to it in the game scene.



9. Finally, you can use the following code inside of `physicsWorld(_:didBegin:)` to make sure the game correctly credits Mr. Pig when he brings home the bacon. :]

```
if contactNode.physicsBody?.categoryBitMask == BitMaskHouse {
    if game.bankCoins() == true {
    }
}
```

Once a collision between the pig and house occurs, you use the provided `game.bankCoins()` method to tally all the collected coins and add them to the actual score. I'll explain the empty `if` statement in the next part. :]

Note: As always, you'll find the solution for this challenge under **projects/challenge/Mr.Pig/**.

Audio in SceneKit

Mr. Pig is nearly done, but where are the sound effects? One of the biggest mistakes a game developer can make is to underestimate the power of audio.

Sound is so powerful that the scariest movie ever made could be comedic without the right audio. Go ahead, put in a classic suspense film like "Rear Window" and mute it. Tell me how long you manage to stay interested. Three minutes — five, maybe?

In particular, ambient sounds create atmosphere and bring your game environment to life. Sound effects let your audience experience every little jump, bump or crash. Music can tap into that deep, dark, scary place inside all of us just as readily as it pulls out our giddy inner children.

In fact, even before there were games and movies with elaborate audio tracks, silent movies were accompanied by ivory-tickling piano players.

Thank goodness the good folks at Apple realize the importance of sound! They added some really cool sound capabilities into SceneKit.

Here are a few important audio elements in SceneKit:

- **SCNAudioSource**: An *audio source* is an object that represents an audio file such as music or a sound effect. It can be preloaded into memory or streamed in real-time.
- **SCNAudioPlayer**: With an *audio player* you can play back an *audio source* as 3D spatialized audio using the position of an **SCNNNode** object.
- **SCNACTION.playAudio(_:waitForCompletion:)**: A special action you can run on an SCNNNode that will play back an *audio source*.

Add music

To start your exploration of sound, you'll add music to set the overall tone for your game.

SceneKit puts a few special objects at your fingertips that are especially for playing music.

In **ViewController.swift**, add the following code to `setupSounds()`:

```
// 1
if game.state == .tapToPlay {
    // 2
    let music = SCNAudioSource(fileNamed: "MrPig.scnassets/Audio/
    Music.mp3")!
    // 3
    music.volume = 0.3;
    music.loops = true
    music.shouldStream = true
    music.isPositional = false
    // 4
    let musicPlayer = SCNAudioPlayer(source: music)
    // 5
    splashScene.rootNode.addAudioPlayer(musicPlayer)
}
```

Take a deeper look at what this code does:

1. This makes sure that the music only plays while on the splash scene.
2. This creates an SCNAudioSource object from **MrPig.scnassets/Audio/Music.mp3**.
3. What follows are a few properties that configure the audio source.
 - `volume`: Controls the volume at which the audio source plays back.
 - `loops`: Controls whether the audio source loops or not.

- `shouldStream`: Controls whether the audio source is streamed from its source or preloaded into memory. Typically music and large audio files should be streamed, but for small sound effects, it's better to preload them into memory for faster playback.
 - `isPositional`: Controls whether the audio source will make use of 3D spatialized playback.
4. This creates an audio player making use of the music audio source for playback.
5. By adding the audio player to the `rootNode` of the scene, this starts the audio player, and then the music streams from its audio source.

Do a build and run, and this time around look *and* listen.



Now you also know why Mr. Pig's been twerking his little tail off! :]

Adding ambiance

Did you really think a park with two massive highways through its heart could be so silent?

Add the following `else if` block to the bottom of `setupSounds()`:

```
// 1
else if game.state == .playing {
    // 2
    let traffic = SCNAudioSource(fileNamed: "MrPig.scnassets/Audio/
Traffic.mp3")!
    traffic.volume = 0.3
```

```
traffic.loops = true
traffic.shouldStream = true
traffic.isPositional = true
// 3
let trafficPlayer = SCNAudioPlayer(source: traffic)
gameScene.rootNode.addAudioPlayer(trafficPlayer)
// 4
game.loadSound(name: "Jump", fileName: "MrPig.scnassets/Audio/
Jump.wav")
game.loadSound(name: "Blocked", fileName: "MrPig.scnassets/Audio/
Blocked.wav")
game.loadSound(name: "Crash", fileName: "MrPig.scnassets/Audio/
Crash.wav")
game.loadSound(name: "CollectCoin", fileName: "MrPig.scnassets/Audio/
CollectCoin.wav")
game.loadSound(name: "BankCoin", fileName: "MrPig.scnassets/Audio/
BankCoin.wav")
}
```

Here's what's happening in there:

1. This checks if the game is in a .Playing state.
2. This sets **MrPig.scnassets/Audio/Traffic.mp3** as a streaming audio source.
3. Then you start to play the audio source as soon as it's added to the rootNode.
4. This preloads a whole bunch of sound effects that you'll use in the next section.

Build and run, start a game and then look and listen.



Suddenly the park springs to life. You can hear the traffic with sounds of little cars, big cars and even those squeaky old buses. Yippee!

Add sound effects

For your final act, you'll unlock the sound effects so the player can hear every jump, bump and crash.

Start off by giving life to every jump. Add the following line to the bottom of `handleGesture(_:)`:

```
game.playSound(node: pigNode, name: "Jump")
```

This will play a nice little *boing* sound effect every time a valid gesture is handled.

Note: This uses a helper method found in `GameHelper` to play a sound. Under the hood, all it does is run a `playAudio(_:waitForCompletion:)` action on the node you pass it by using a preloaded audio source. You can take a look at how it does this by browsing **GameHelper.swift**.

What about when Mr. Pig stumbles into an obstacle? Add the following sound effect code inside the second guard statement:

```
game.playSound(node: pigNode, name: "Blocked")
```

This code will block gestures matching the `activeCollisionBitMask` at the top of `handleGesture(_:)`, just before the return statement.

Now blocked gestures will make a short little *thump* when the player tries to jump into an obstacle.

Coins need sound too! Add the following line just after the call to `game.collectCoin()` inside of `physicsWorld(_:didBegin:)`:

```
game.playSound(node: pigNode, name: "CollectCoin")
```

Collecting coins certainly sounds a little cooler, but the effect is somewhat muted. The reason is that the player hasn't scored yet; he needs to bank that coin in order to get the full audio experience.

Add the following sound effect to that moment when the pig makes contact with the little house.

Go back into `physicsWorld(_:didBegin:)`, to that empty `if` statement from earlier; the one checking the return value of `game.bankCoins()`. You only want to play a sound if there are actual coins available to bank, so add the following line, inside the `if game.bankCoins() == true` statement:

```
game.playSound(node: pigNode, name: "BankCoin")
```

Ah, yes! Once the pig jumps into his little house, that familiar sound effect lets the player know the scoreboard has been updated.

Cha-ching! :]

Last but not least is the moment of impact when pig meets bumper, and he floats away to porker heaven.

Still inside of `physicsWorld(_:didBegin:)`, add the following line of code inside the if statement that handles the moment when `pigNode` makes contact with a vehicle, but place the code just before the call to `stopGame()`:

```
game.playSound(node: pigNode, name: "Crash")
```

Do a final build and run, and enjoy the full Mr. Pig experience with music, ambiance and sound effects!



And with that, you just finished this game. Congratulations! :]

Where to go from here?

The final project can be found under the **projects/final/Mr.Pig/** folder.

In this chapter, you realized the value and impact of sound. Thanks to SceneKit, it's easy to add sounds to all of your future titles.

Mr. Pig has so much unexplored potential just waiting for discovery. Here are a few ideas to consider:

- **Voxel Graphics:** Voxel graphics look sharp and are super easy to create. It's the perfect style for when you need 3D but can't or would prefer not to go into great detail.
- **More characters:** You should definitely add more characters to your game. Mr. Wolf, the menacing figure behind that atrocious mall and traffic, is a big bad bully, and he would love nothing more than to troll Mr. Pig from time to time. Rumor has it that he's got his eyes on the park and cute little house. He could be a good motivator to stay away from certain parts of the park or take on the role of an evil boss Mr. Pig must defeat.
- **More obstacles:** Go and explore a nearby park and see what else you could add to the park. There could be a fountain, some park benches, birds, a flock of flamingos...
- **More actions:** Use actions to add juice to your game. The more elaborate and fun the animations, the more enjoyable to play.
- **Go big:** At the moment it's a small park — surely you can think up some other clever designs to make the park bigger and more interesting. Why not add power-ups and traps to keep our hero on his hooves?

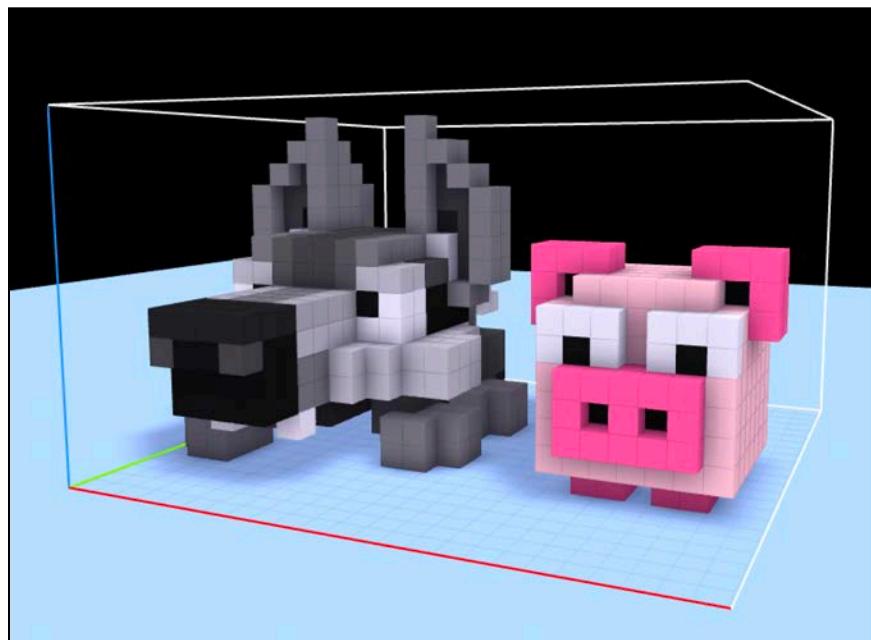
Now for your final challenge: free your mind, think outside the box and unleash your newly found SceneKit powers onto the world! :]

Section VI: Bonus Chapter

Surprise! An entire section with bonus content.

In this section, you'll learn how to create your very own 3D art for your SceneKit games. In the process, you'll learn how to create Mr. Pig from scratch. You'll also learn how to import your graphics into SceneKit.

Oh yeah, and there's a Mr. Wolf too! :]



[Chapter 24: 3D Art for Programmers](#)

Chapter 24: 3D Art for Programmers

Chris Language

Since the dawn of time, humans have embraced their inner creativity. From the primitive cave paintings of ancient hominids, to the majesty and grace of such masterpieces as Leonardo da Vinci's "Mona Lisa", art has constantly evolved with time. You stand at the dawn of a new era, where the modern programmer will gift the world with *programmer art!* Grog and Leonardo would have been proud. :]

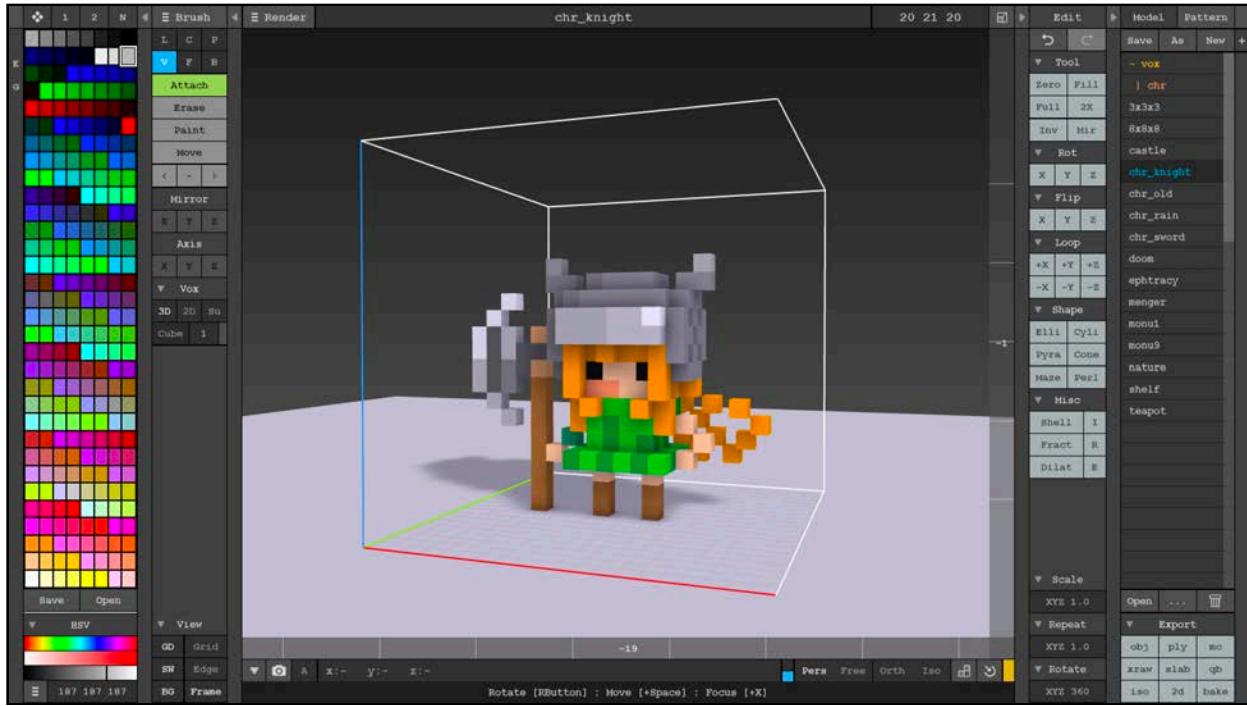
Prototyping apps, especially games, requires graphics — lots of graphics. Proper graphics take a very long time to create, and time is something most coders just don't have. Programmer art is a nice compromise; you create a rough concept of the required art and use it as a placeholder until you can get around to making (or paying for) some decent game art.

Getting started

Voxel graphics are a super easy and extremely fast way to create 3D content, and have become extremely popular for this reason. Out of the many tools available, **MagicaVoxel** is one of the best. Why? Because it's free! Oh, and it's pretty darn awesome too. :]

Note: Grab yourself a copy of MagicaVoxel at <https://ephtracy.github.io> and install it before you continue. It's only a single download and runs on both macOS and Windows. Be sure to thank @ephtracy on Twitter for such an amazing free product.

Once installed, you'll be greeted by a very interesting and unique UI. This is clearly a program created by a programmer, for programmers. Fear not, there is definitely some method to this madness; once you get the hang of it, you'll fall in love with it.



You'll notice that the UI is divided into expandable columns. Here's what you'll see from left to right:

- **Color Palette:** The left-most column is your color palette. Here you can pick and choose from a whole spectrum of colors. You can even pick your very own custom color right at the bottom.
- **Brush:** This is the second column, right next to the Color Palette. Here you can pick your brush mode. You can choose from modes like **V** (Voxel), **F** (Face), **B** (Box), **L** (Line), **C** (Center) and **P** (Pattern). You can also choose an action to **Attach**, **Erase**, **Paint** or **Move** voxels using the current brush.
- **View Options:** You can find this section just below the Brush section in the same column. Here you can quickly toggle various display options like **DG** (Display Ground), **SW** (Display Shadow), **BG** (Display Background), **Grid** (Display Grid), **Edge** (Display Edges) and **Frame** (Display Frame).
- **Editor:** This middle section is where you'll edit all your voxel creations. You can navigate through this area with your mouse. **Rotate** by holding the right-mouse button down while dragging, **Zoom** by rolling the mouse wheel up or down, and perform the selected **Action** by clicking the left-mouse button on the scene. Set the **Name** of your voxel creation at the top of the editor. You can also set the **Dimensions** of your voxel creation; this model has the dimensions 20 21 20 noted at the top-right side of the editor.

- **Edit Options:** The second last column on the right contains a set of common, useful operations that you might want to perform on your voxel creation. **Zero** empties the model, **Fill** fills the model with same color, **Full** sets the model to full volume. There are also operations to **Rotate**, **Flip** and **Loop** your model around an axis.
- **File Options:** The very last column is where you can **Load**, **Save**, **Save As**, **Duplicate** and even **Delete** voxel models and patterns.
- **Export Options:** You'll find this section right at the bottom of the right-most column. These are all the available export options MagicaVoxel has to offer.

Note: Feel free to play around a bit first. Don't be afraid, you won't break anything. Review the above sections again in more detail to get a good feel for the entire UI before you continue with the next section. There is also an excellent video tutorial on their site.

Creating a voxel model

Time to get those clean hands dirty and build something spectacular: a handsome little Mr. Pig!

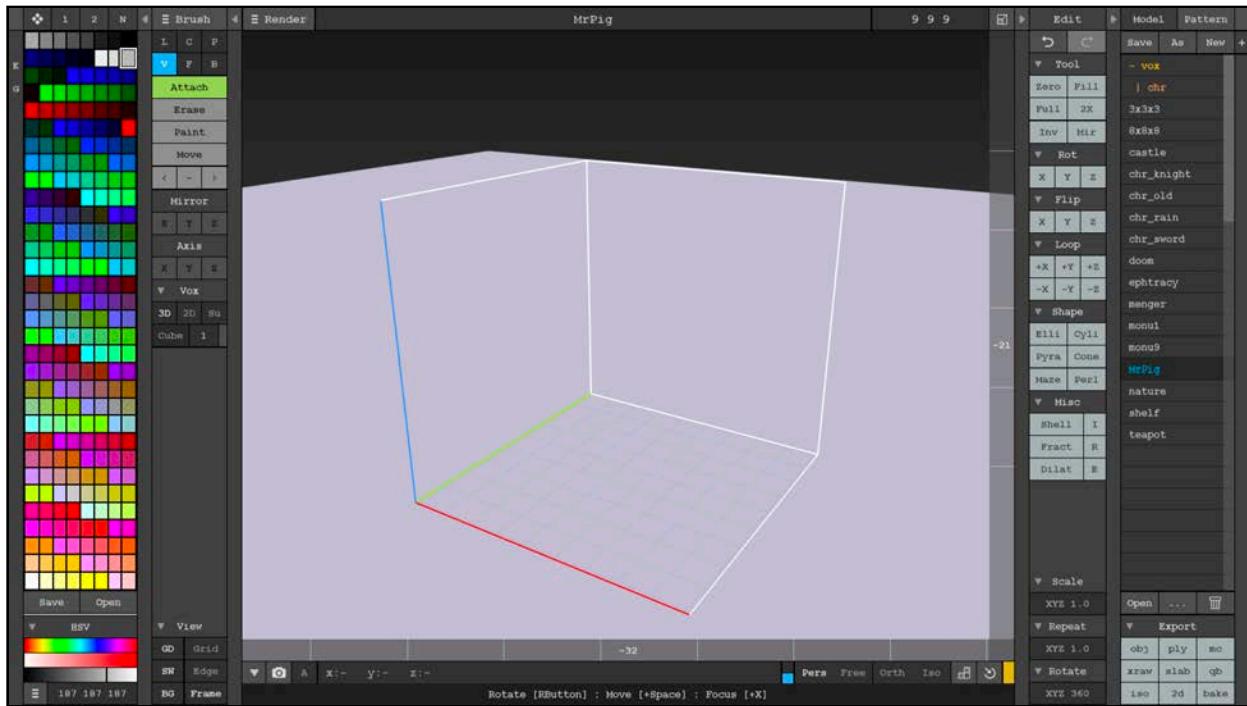
In this section you will follow precise instructions to build your own Mr. Pig. The process is quite similar to how you'd dissect a poor little frog in Biology class — only in reverse. :]

Note: The following workflow covers most of the basic techniques used to build voxel models using MagicaVoxel. Follow the steps carefully, and take particular notice of how you configure the brush in each step.

Creating a new model

Start off by creating a blank slate for yourself.

Select **New** under File Options to create a new model. Set the voxel model dimensions to 9 9 9, then click **Zero** under the Editor Options to clear out the entire model:



Name the model **MrPig** at the top of the editor and press Enter when you're done. Select **Save** when prompted:



Note: Your model will also now be available on the right-hand side, under the File Options.

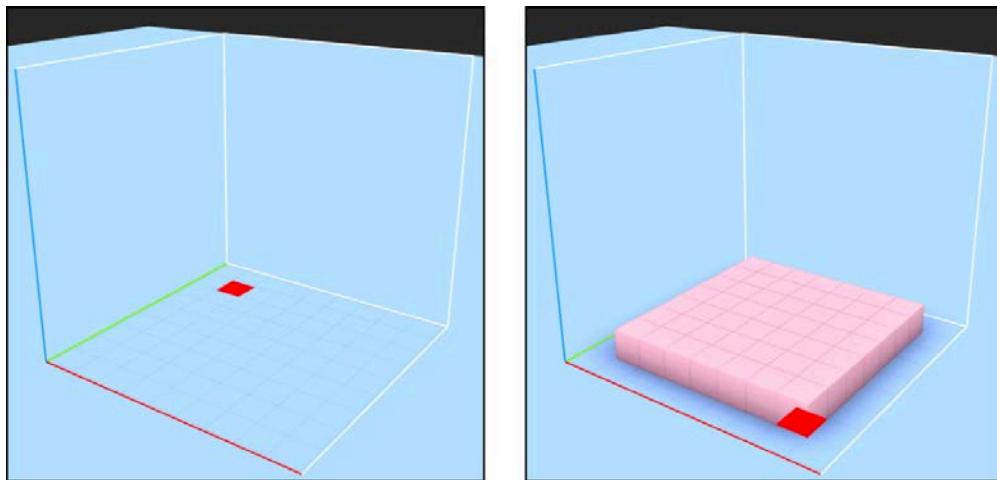
Creating the base

You'll start by creating the base of Mr. Pig's body.

Select a nice light piggy-pink color from the color palette on the left.

Set the brush by pressing **B** to go into **Box Mode**, then press **T** to select **Attach**.

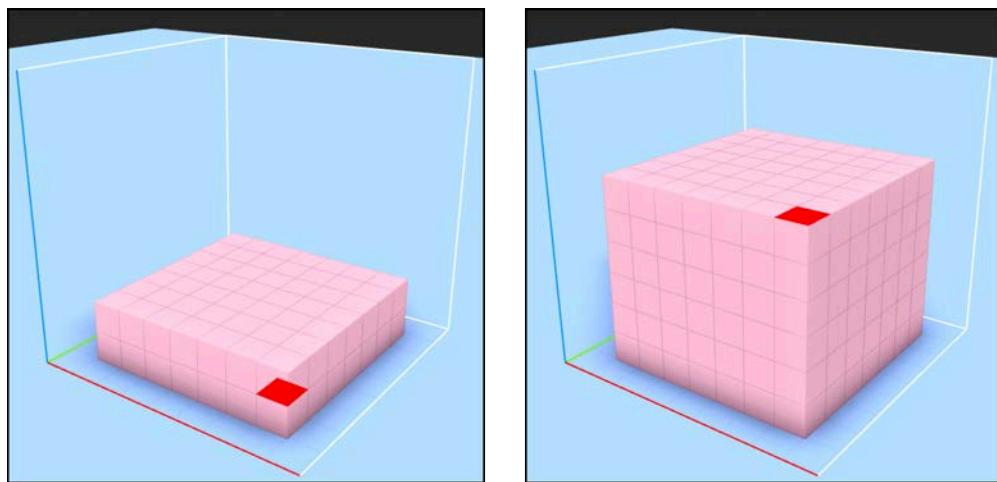
Hover to position (x: 1, y: 7, z: -1). **Left-click** and hold the mouse button while dragging to (x: 7, y: 7, z: -1). Release once you're there to create a one voxel-high base:



Extruding the base

Change the brush by pressing **F** to go into **Face Mode**, and make sure **Attach** is still selected.

Left-click the top face of the base layer to extrude it one voxel upwards. Repeat this until the base box is 6 voxels high:



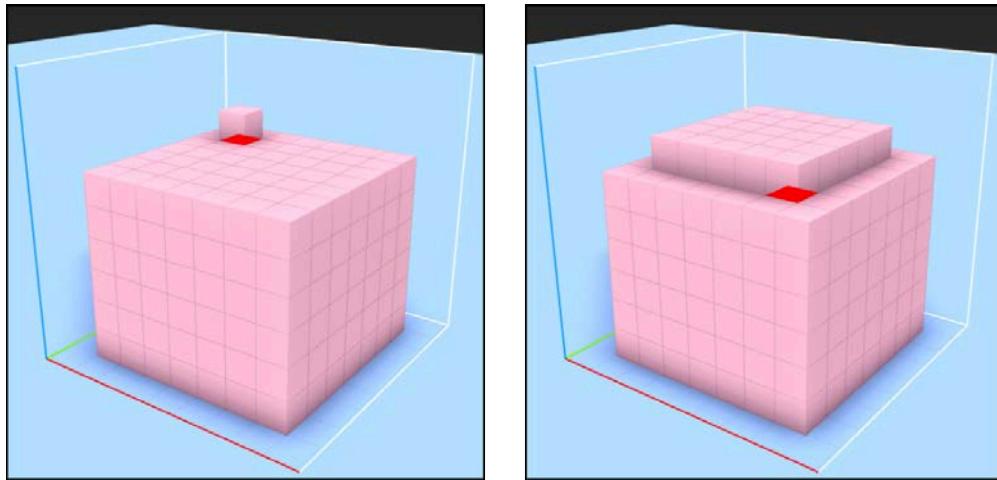
You can toggle **Grid** in View Options to help see the dimensions more clearly.

Creating the head

Now to create the section that houses the most important part of Mr. Pig — his brains! It's also important to point out that the accuracy of a voxel pig's anatomy is never to be questioned. :]

Change the brush back to **Box Mode** by pressing **B**, again making sure that **Attach** is selected.

Start off at position (x: 2, y: 6, z: 5). **Left-click** and drag to (x: 6, y: 4, z: 5):

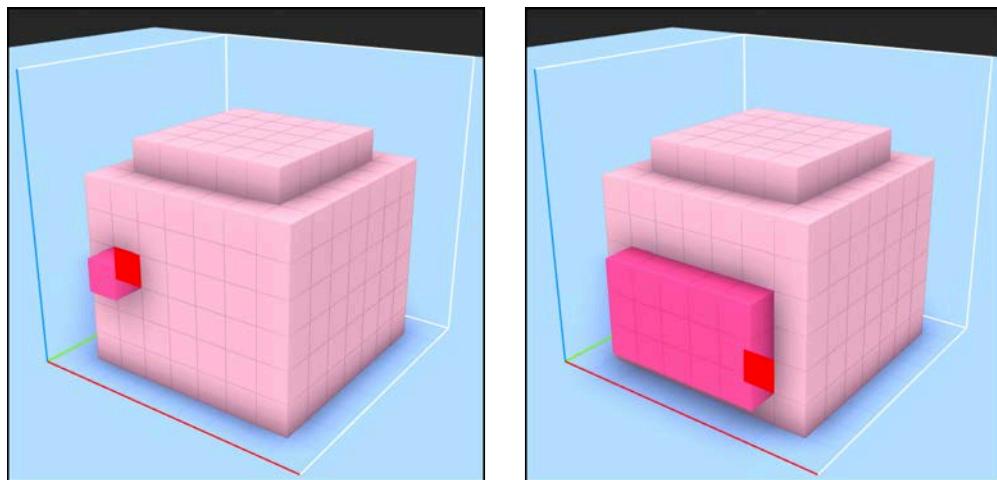


Creating the snout

Now to construct the second most important part of Mr. Pig — his snout!

Select a dark pink color from the color palette on the left.

Using the same brush settings from the previous step, create a box from (x: 2, y: 1, z: 3) to (x: 6, y: 1, z: 1):

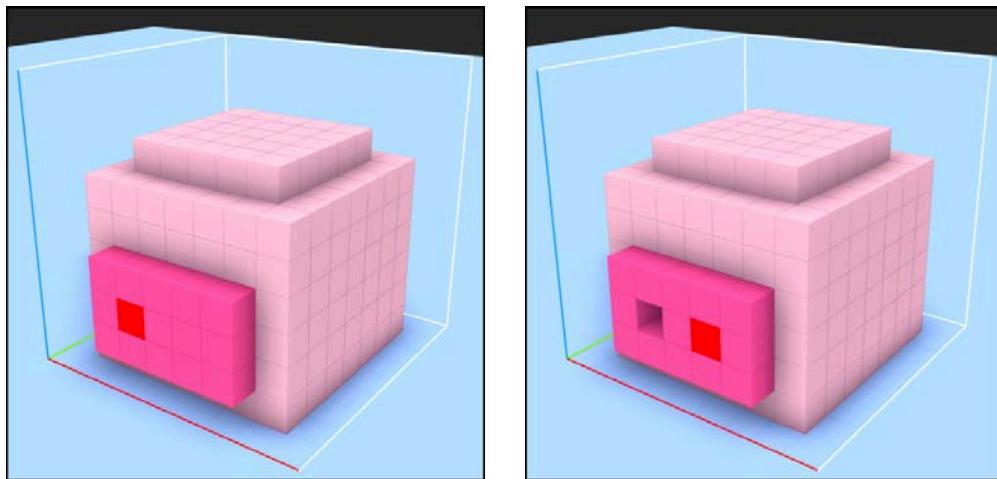


Carving out nostrils and eyes

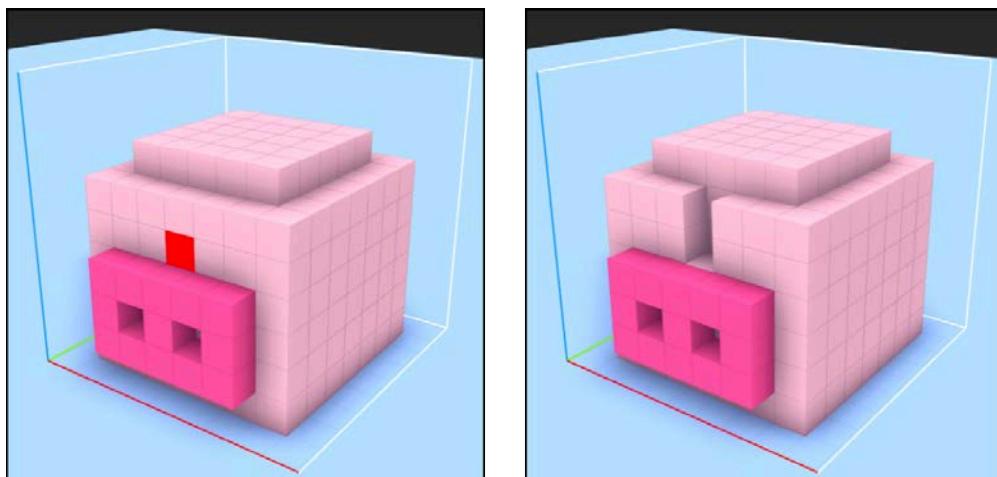
How on earth will Mr. Pig sniff out those lovely hidden truffles without actual nostrils in his snout?

Change the brush to **Voxel Mode** by pressing **V**. Then press **R** to select **Erase**.

Erase two nostrils in his snout, using the image below as a reference:



Separate his big eyes too while you're at it:



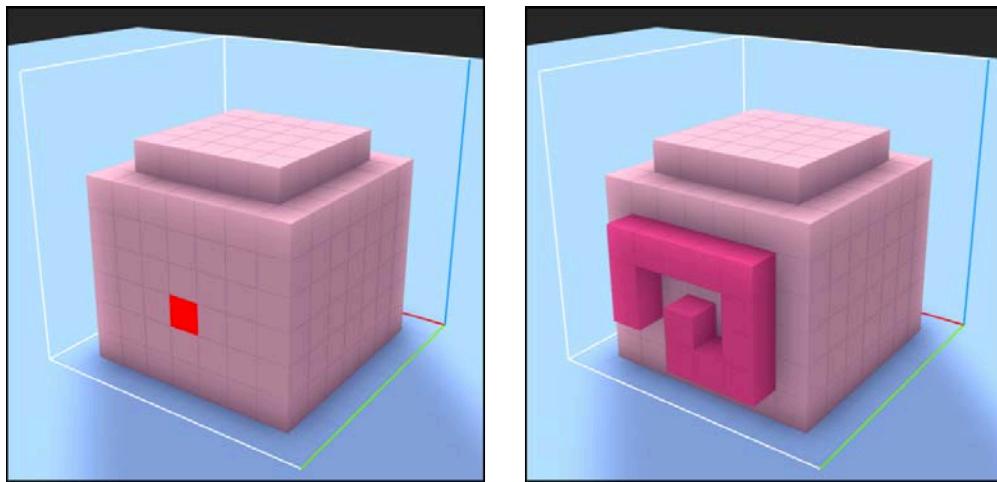
Creating the tail

Time to play Pin-the-Tail-on-the-Piggy. :]

Make sure you still have the same dark pink color selected as before.

Rotate the pig 180 degrees around the y-axis to expose the pig's hind-side.

While still in **Voxel Mode**, press **T** to select **Attach** and build a little spiral tail starting at (x: 4, y: 7, z: 2) so that it resembles this image:



Once done, rotate that pig 180 degrees around the y-axis again so that you can finish up his front-side.

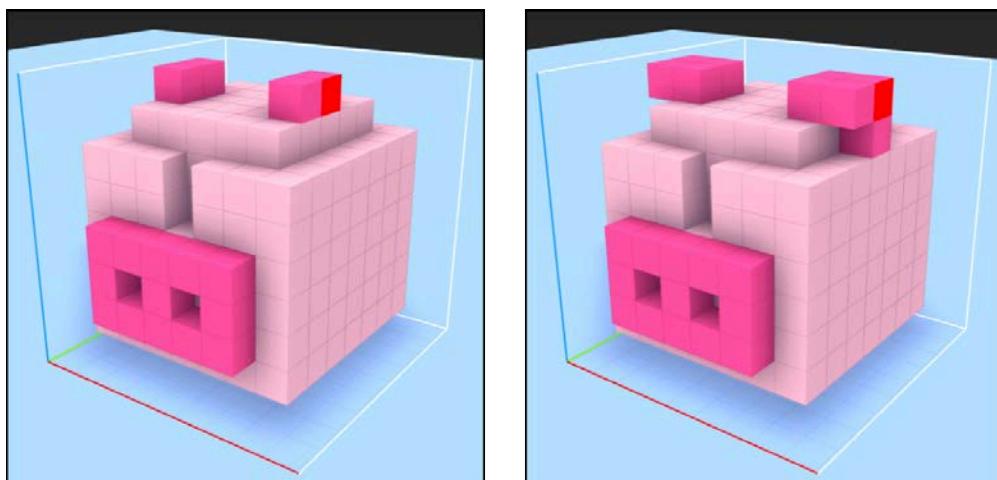
Adding ears

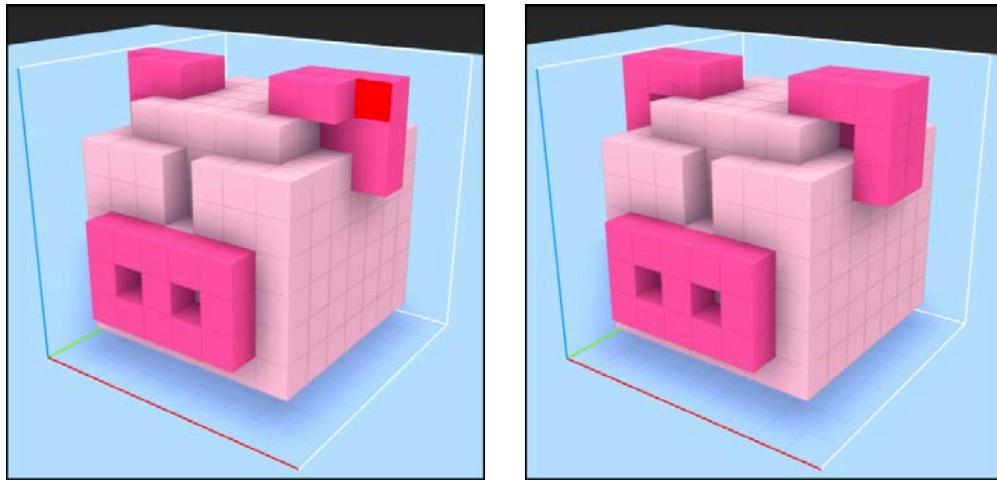
Mr. Pig needs to listen for oncoming traffic; you'll give your pig the gift of hearing with some ear flaps.

Use the same dark pink color and brush settings as before.

Press **1** to turn on mirroring along the x-axis. You will notice the mirror **X** button will turn on. Whatever you do now on one side will automatically mirror to the other side.

Start building one ear, voxel by voxel, and you'll see the other ear built at the same time. Reference these images to get a sense of where to start and where to end:





Adding legs

What do you call a pig without legs? Ground pork! :]

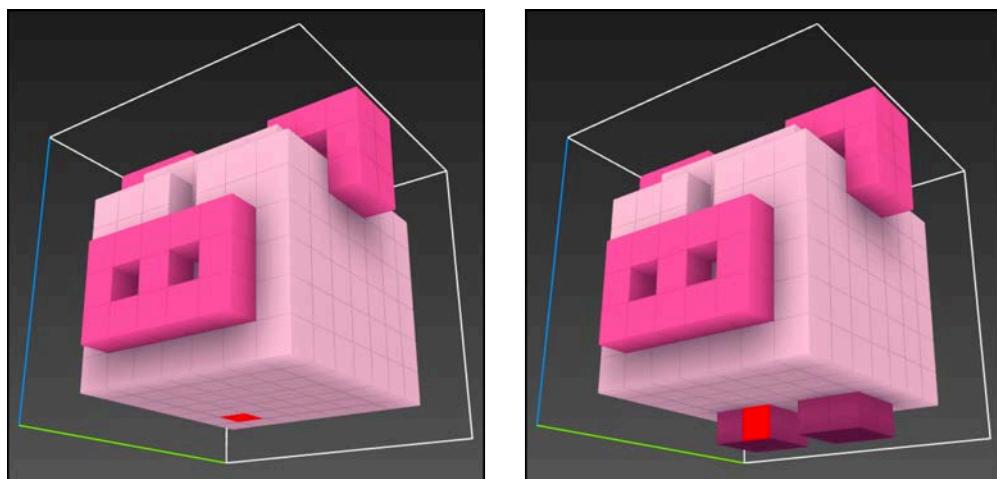
Right now, Mr. Pig sits on the bottom of the bounding box, so you need to move him upwards to make room for his little legs.

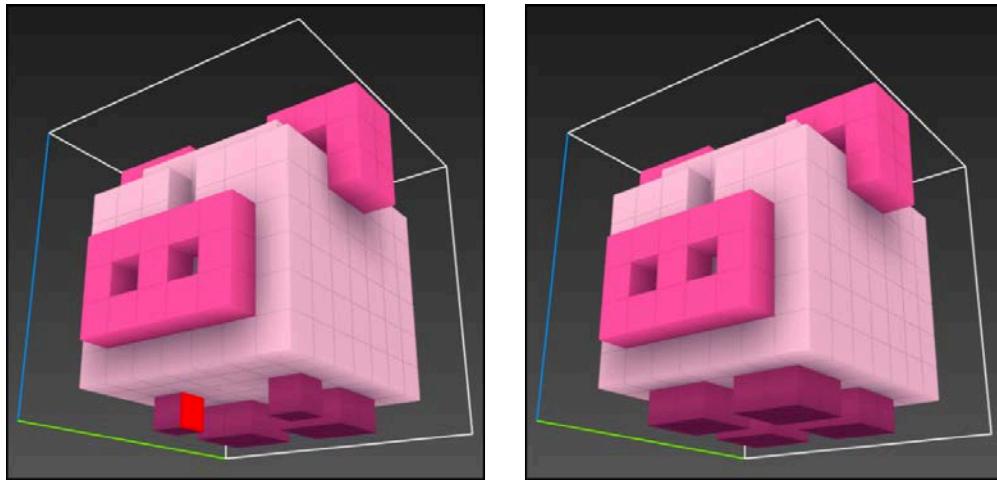
You can either go into **Move Mode** and drag your model one voxel upwards or hold down the **Command** key and drag one voxel upwards to get the same effect.

Now, rotate the pig upwards so that his belly is exposed.

With the same color and brush settings, make sure mirroring is still turned on along the x-axis.

Start building the hind legs first, then the front legs. Again, use the images below as reference:



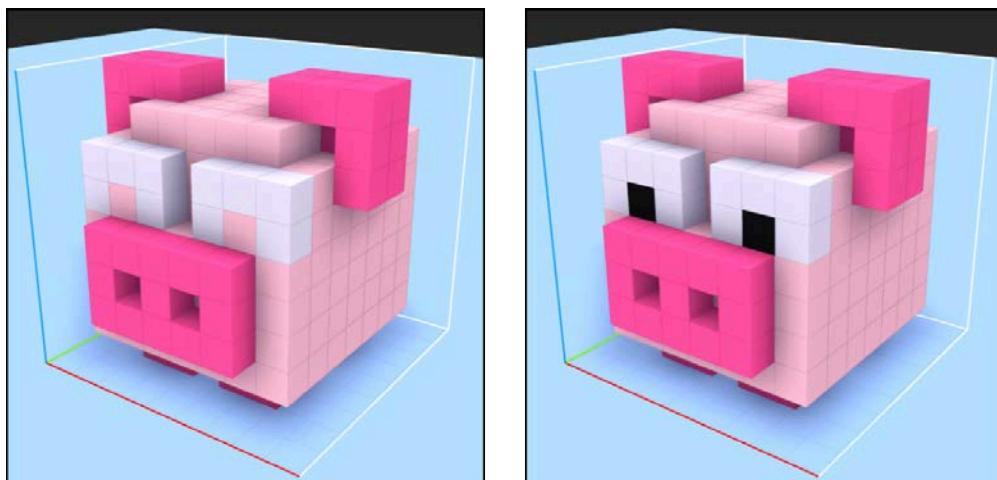


Finishing touches

You're almost done; all that's left is to color in the missing bits and pieces.

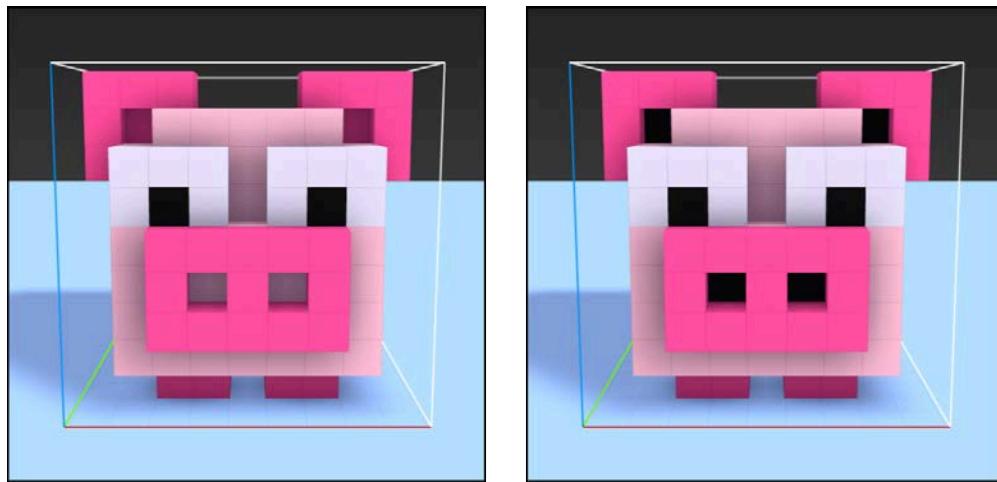
To do that, go into **Paint Mode** by pressing **G**.

Select a white color from the palette on the left and click on the voxels that form the white of Mr. Pig's eyes. Once you're done, select a black color and paint in the pupils:



Next, angle the pig so that he directly faces you.

Paint in his dark ears and dark nostrils like so:



Excellent! You've completed your first voxel model. To top it off, you've also learned quite a few useful tips and tricks along the way.

Exporting the voxel model

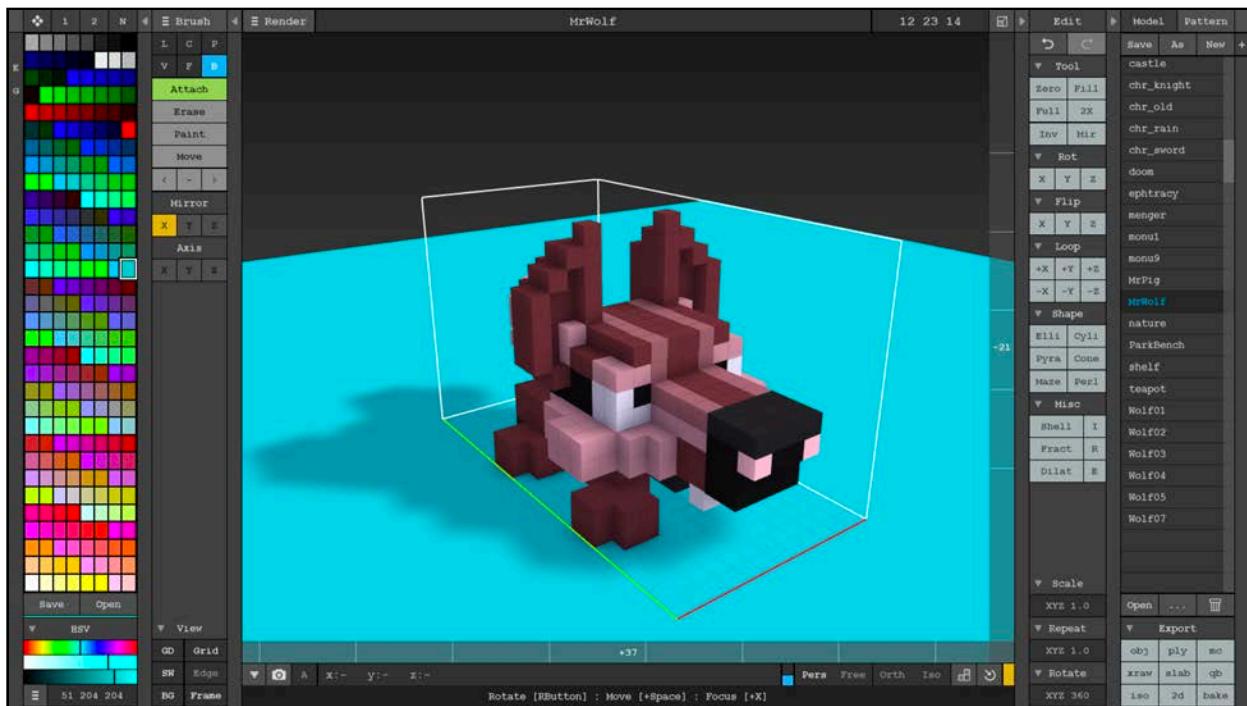
Now that you've created some awesome voxel art, you're probably eager to use it in your game! Unfortunately, SceneKit doesn't directly support MagicaVoxel's native file format **.vox**. Luckily, there's a way to save your bacon, and that is to export your voxel model in the more commonly used **.obj** format.

The **.obj** file format, is an open-standard geometry definition developed by **Wavefront Technologies** and supported by many 3D authoring tools.

Exporting a voxel model from MagicaVoxel is as easy as falling off a hog. Er — log. :]

Exporting a voxel model as an **.obj**

Mr. Pig needs a nemesis — enter Mr. Wolf!



Note: There's a special surprise waiting for you under the **resources** folder. In there you'll find a **MrWolf.vox** file, which you'll use to explore exporting **.vox** files to **.obj**. Copy **MrWolf.vox** to **Applications/MagicaVoxel/vox**, then open up the model in MagicaVoxel.

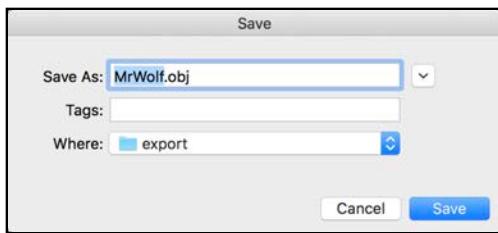
Once you've got Mr. Wolf loaded, you can take a look at the steps to export him in a useful format.

To export any voxel model from MagicaVoxel as an **.obj**, simply click **obj** under the **Export** section at the bottom right:

| ▼ Export | | |
|----------|------|------|
| obj | ply | mc |
| xraw | slab | qb |
| iso | 2d | bake |

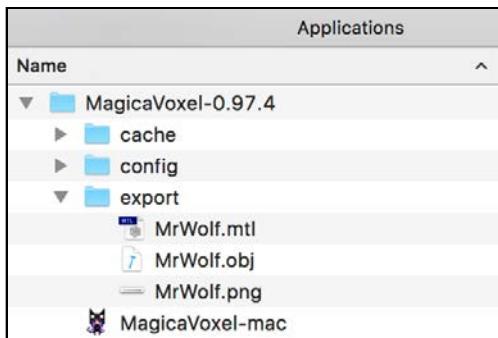
If you don't see the option listed, simply click **Export** to expand the menu.

Supply a file name and destination for the files to be exported. For now, leave everything at their default and click **Save**.



Excellent — you're all done. Yup, it's that simple!

You'll find your exported files under **Applications/MagicaVoxel/export/**. You can also find a copy of these in the **resources** folder of your project for your convenience.



MagicalVoxel exports three distinct files as part of your model:

- **MrWolf.mtl**: This is the material library file that contains definitions for colors, textures and a reflection map.
- **MrWolf.obj**: This is the Wavefront **.obj** file that contains the geometry information for your voxel model.
- **MrWolf.png**: This is your voxel model's diffuse texture map, which contains all the colors used in your model.

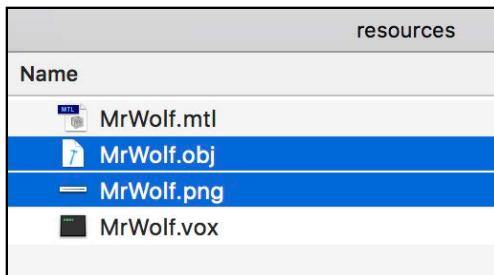
Importing voxel models

Now that you've exported your voxel model, you need to import it into Xcode, then convert it into a proper SceneKit scene file.

Note: Before you continue, open up the starter project under **projects/starter/Mr.Pig/**. This project continues where the previous chapter ends. As mentioned before, you'll also find the exported files required for the next steps under **resources** if you didn't follow the steps in the last section.

Importing .obj into Xcode

With the starter project open, locate the additional files in Finder:

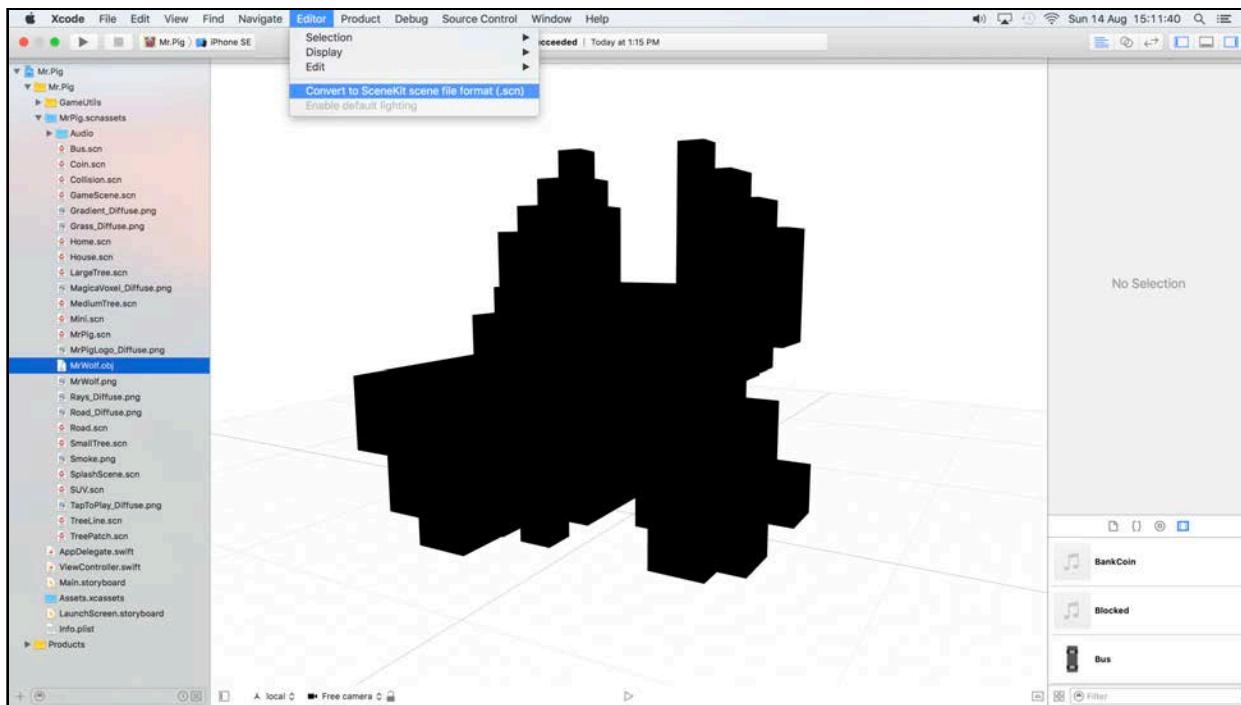


Select both **MrWolf.obj** and **MrWolf.png** and drag them into your Xcode project under **MrPig scnassets**.

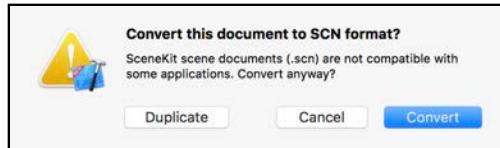
Converting .obj into .scn

Make sure you've got the **MrWolf.obj** file selected under the **MrPig scnassets** folder. Don't worry if the model is all black in color; you'll fix that next.

Under the menu options find **Editor**, then select **Convert to SceneKit file format (.scn)**:

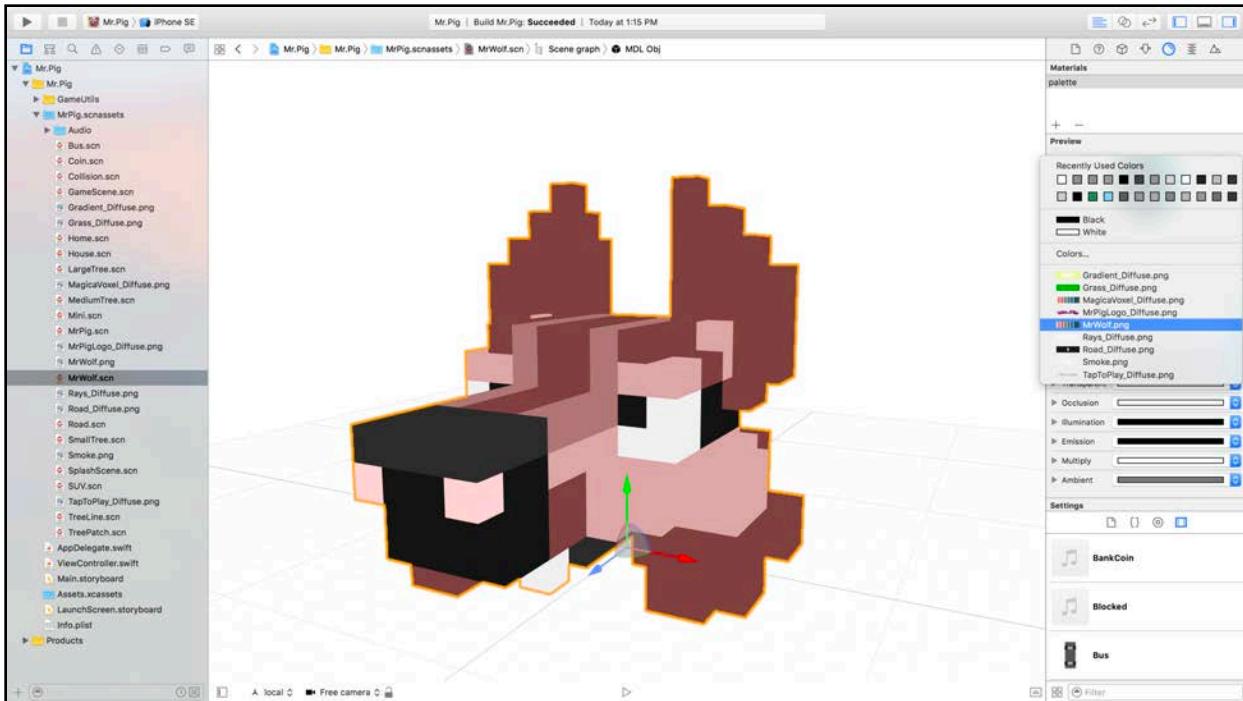


Here you can choose whether you want to create a **Duplicate** of your original **.obj** file, or simply convert and replace it entirely with the **.scn** version. Choose **Convert** to continue:



SceneKit converts the **MrWolf.obj** file into a proper **MrWolf.scn** file. You now have a proper SceneKit version of your voxel model.

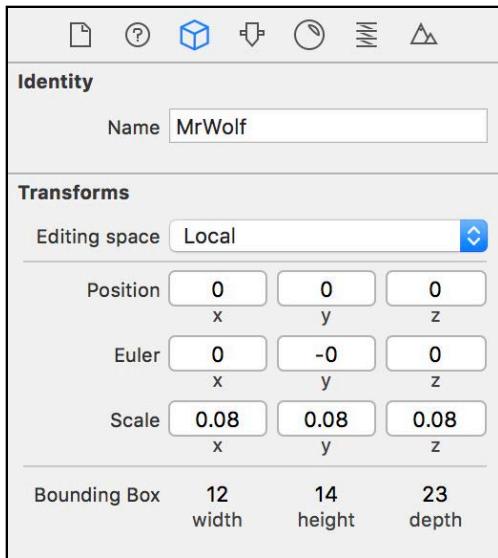
Select the wolf node within the scene and open the Materials Inspector. Change the **Lighting model** to **Lambert** and change **Diffuse** so that it uses **MrWolf.png** as a texture:



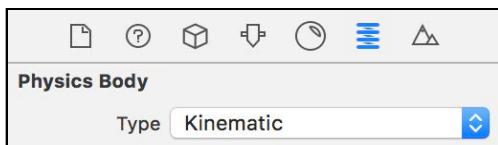
Configuring the voxel model

Now that you've got your voxel model imported and converted into a SceneKit file, you'll need to add some basic configuration to make the model fit in with the rest of the game. Mr. Wolf needs a proper name and has to be scaled accordingly.

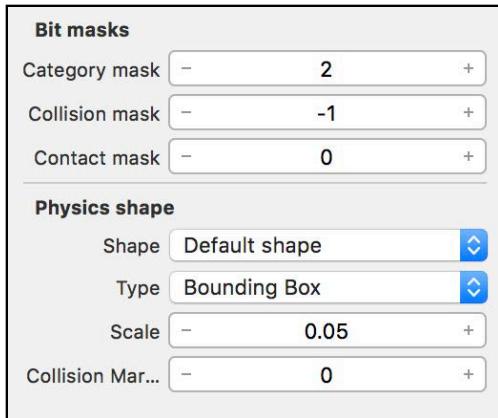
Under the Node Inspector, change the **Identity** to **MrWolf**. Also change the scale down to (**x: 0.08, y: 0.08, z: 0.08**). This scales him down to same size as Mr. Pig:



Move on to the Physics Inspector and change the **Type** of the physics body to **Kinematic**:



Set **Category mask** to 2 and **Collision mask** to -1. Change the **Physics Shape** Type to **Bounding Box** and set the Scale to **0.05** so the collision geometry fits the body of the wolf more closely.



You're all done — Mr. Wolf is ready for action!

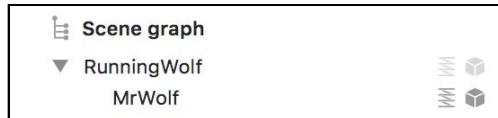
Note: You can find the complete version of this project under **projects/final/Mr.Pig/**.

Challenge

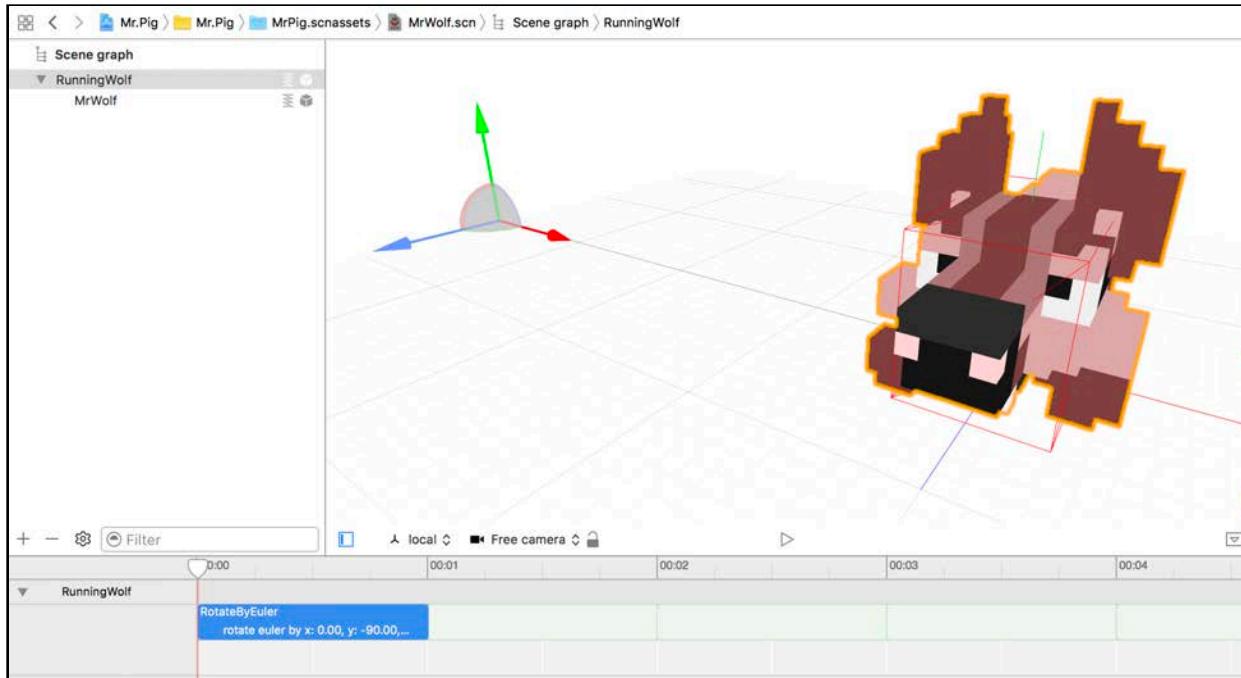
Time for a nice little challenge! Add Mr. Wolf into the game and make him chase his tail around the bushes. Are you up for it? Don't worry, here's a few tips to help you along the way.

Select **MrWolf.scn** and make a few little changes:

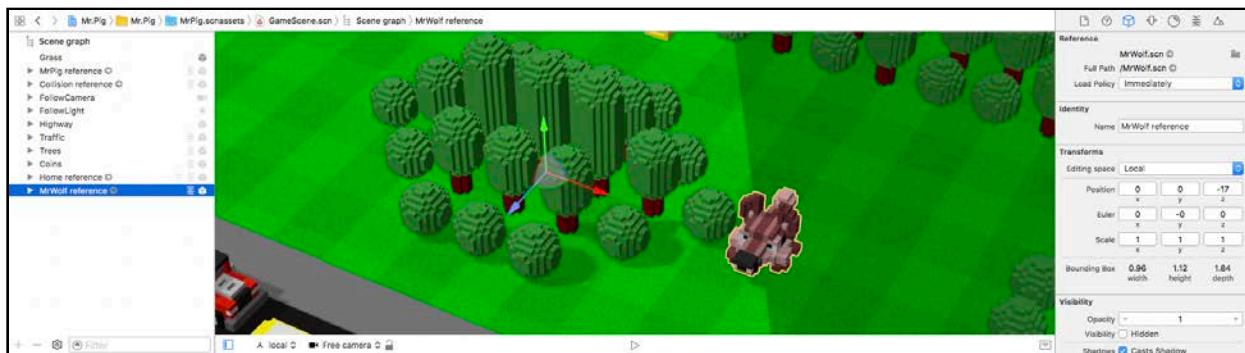
- Create a new parent node for **MrWolf** and name it **RunningWolf**.



- Offset **MrWolf** by 4 units on the x-axis. Then add a **Rotate Action** to the *parent* node and rotate it by -90 degrees in an endless loop. Mr. Wolf should run in a big circle when you press the play button.



- Finally, add a reference of **MrWolf.scn** into **GameScene.scn**. Place him at position (x: 0, y: 0, z: -17).



Build and run your game; Mr. Pig better watch his chinny-chin-chin, because there's a crazy Mr. Wolf chasing his own tail around the bushes in the park! :]

Note: You can find the final version of this project under **projects/challenge/Mr.Pig/**.

Where to go from here?

You accomplished a lot in this chapter:

- **MagicaVoxel:** You now know how easy it is to create your very own stunning voxel graphics.
- **Exporting:** You learned how to export your voxel models into a commonly used **.obj** format. Now you can use your voxel models with any available 3D authoring tool out there.
- **Importing:** You also learned how to import **.obj** files right into Xcode, and how to convert them into proper SceneKit files.

Creating art for your game has never been easier than with voxel graphics; in a relatively short amount of time, you've been able to recreate Mr. Pig and import Mr. Wolf into your game. Programmer art using voxel graphics can be a great time-saver, but it might also expose your hidden talent for fun and funky game art!

Now that you've got mad voxel skills, nothing is going to stop you from creating your very own mega-hit voxel styled game!



Conclusion

We hope you enjoyed this book! If you worked through it all, you created four epic games from scratch using SceneKit and Swift — from colorful, exploding geometry, to a shiny paddle with a bouncing ball; a beautiful maze, up high in the sky, right down to a cute little pig that twerks. You also expanded the reach of the games by targeting other platforms like macOS, tvOS and watchOS. You even re-built Mr. Pig from scratch, voxel by voxel, and went through the process of importing SNF files using an exported MagicaVoxel model right into Xcode.

You now have the knowledge to make your very own hit game. Why wait any longer?

Got a great idea? With SceneKit, prototyping your app is child's play. Share it with your friends, then use their feedback as inspiration to keep on improving it. Don't forget about adding juice: music, sound effects and stunning graphics. Keep on pushing, until you make that final push and publish your game for the whole world to enjoy!

We can't wait to see what you come up with! Be sure to stop by our forums and share your progress at www.raywenderlich.com/forums.

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www.raywenderlich.com/reviews

Thank you again for purchasing this book. Your continued support is what makes the tutorials, books and other things we do at raywenderlich.com possible. We truly appreciate it.

Best of luck in all your 3D Apple Game adventures,

— Chris L., Ken, Wendy, Toby, Chris B. and Tammy

The *3D Apple Games by Tutorials* Team