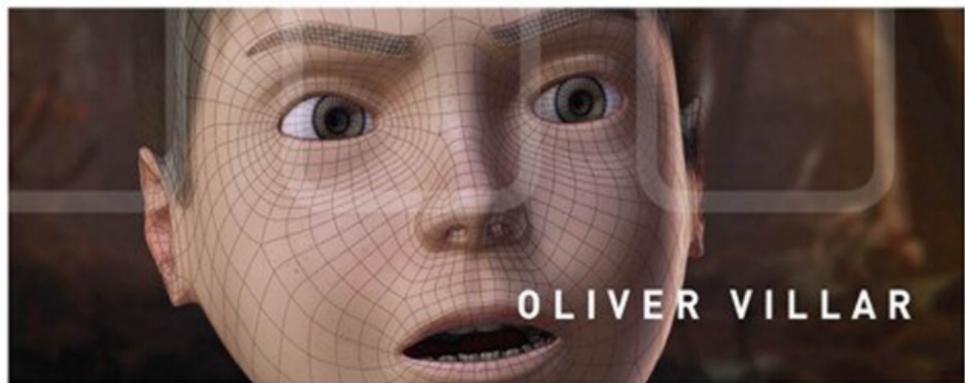


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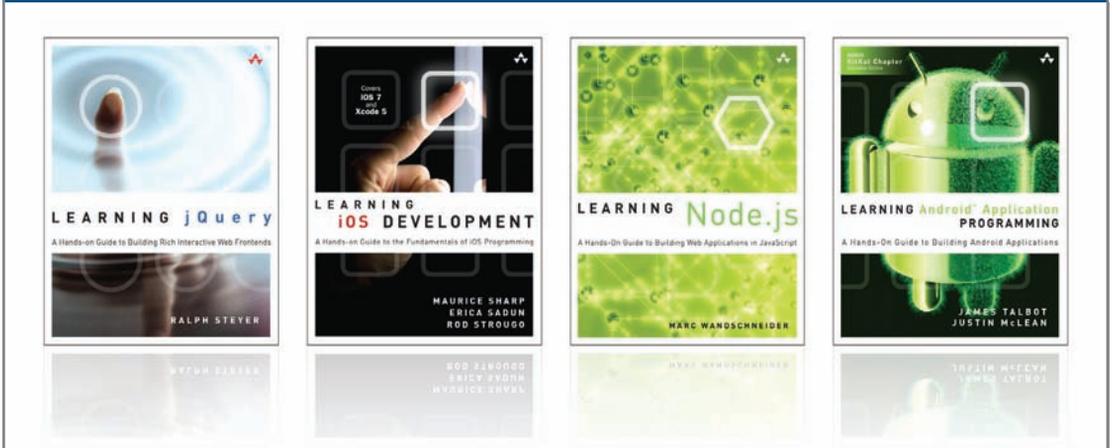
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Learning Blender

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Learning Blender

A Hands-On Guide to Creating 3D Animated Characters

Oliver Villar

◆ Addison-Wesley

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*To my parents and family, for their support in my journey.
To my friends, for their patience, happy moments, and encouragement.
To everyone who crossed paths with me at some point of my life:
I've been able to learn a lot from all of you.*



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Preface

Creating animated characters is a skill that requires a lot of practice and dedication. It involves a wide variety of very different skills and that's what you're going to learn as you progress through this book's chapters. Let's quickly find out what this book is about and what you can expect from it. Also, if you already have experience creating 3D characters with other software, you've come to the right place, as you'll find some instructions on how to switch between two different programs, which can be frustrating and occasionally even more difficult than learning how to create 3D characters.

Welcome!

Welcome to *Learning Blender: A Hands-On Guide to Creating 3D Animated Characters*. In this book, you'll learn how to use Blender to complete a complex project. The book covers every part of the process so you will understand what is involved in the creation of a 3D character and can decide which part of that process you most enjoy and might want to explore further. In other words, this is not a specialized book that will make you a modeling genius or an expert animator; instead, it will help you understand every part of the animation process. The idea is that once you finish reading this book, you will have the knowledge to take any project from preproduction to the final result.

If you're a freelancer (or want to be), this book is tailored for you because freelancers often get small jobs requiring a great variety of skills. Thus, having basic or medium skills in diverse tasks can be more useful than being very good at just a single specific skill.

If you want to work for a big company and prefer to be specialized, it is also helpful to understand the complete animation process; for example, if you're a modeler but you understand how rigging works, when you create your models you'll be able to identify any possible issues your rigger colleagues may encounter and that will help you make their work easier. When you work on a team, you'll only work on a portion of the project, but if you have some understanding of what the rest of the team's job is, your work will be more valuable to them, and everyone will be happier!

You may already be familiar with Blender and want to learn about 3D character creation. In that case, you can probably skip the first three chapters and go straight to the parts of the book that describe character creation. (Do this only if you're completely sure you understand the basics of Blender.)

Finally, if you just want to get started in this amazing world of 3D animation and jump into a fantastic journey, this book will provide you with detailed insights on how

to handle 3D projects. If you've never used 3D software before, don't worry if it initially looks a bit overwhelming—that's normal; the software provides lots of options and unique features that may be unfamiliar to you. While we often tend to be intimidated by what we don't know, if you keep exploring and practicing, you'll soon begin to enjoy the learning process and your results will reflect the effort you've invested. Good luck!

Switching from Other 3D Software

Years ago, I decided to switch to Blender, so I understand what you will encounter. That's why, throughout the book, I share tips about the differences between Blender and other 3D software. I changed to Blender after using commercial software (3ds Max, Maya, and XSI) for years. Back then, when I jumped into Blender (version 2.47), it was not as user friendly as it is now. It's still very unique software and when you open it for the first time, it may look a little alien to you.

Don't worry, it's completely understandable if it doesn't make sense right away—just don't give up! It won't be easy at first. It took me three or four times checking different versions of Blender until I finally decided to go for it and start learning it for good. You'll see “weird” things, like right-click selections (we'll go through this one in the first chapters) or the omnipresent 3D cursor, with apparently no function at all, that you'll always see in a scene.

Also, you'll have to learn a lot of shortcuts. This is what makes the learning curve for Blender very difficult at the beginning, but once you get used to shortcuts, you'll love them because they will allow you to work a lot faster in the long run. For example, before I used Blender, it was difficult for me to work with fewer than three different 3D views on the screen at the same time. Now I work in full screen with only one view, in a much more relaxed way. It's like using the *Expert Mode* in other software all the time!

I've taught a lot of people how to use Blender and have talked with many others who came to Blender from another animation software; what usually happens is that they struggle at first (that's why most people give up and stick to commercial software), but once they understand the basics, they start to love it and are soon devoted to it. They find that a lot of tasks are just easier or faster to do in Blender than they are in other software.

I really encourage you to keep exploring Blender and find out what it has to offer. I've learned to use a lot of different kinds of software and tools, and after repeating the learning process and switching between software several times, I've come to know the methods that work best for me, which I'll share with you. The key to adjusting successfully to change (not only in software, but in any aspect of work or life) is to learn how to *adapt yourself and be flexible*. To some extent, you have to open your mind to allow the new software or work situation to get in. For example, some people might complain that Blender doesn't have a particular tool or that a certain task was easier to accomplish in another type of animation software. Avoid this negative attitude at all costs and *try to understand the new software*, as each type of software has a different philosophy behind its

development and work flow. Complaining is a waste of time and energy you could otherwise invest in something much more useful, like learning how to use the software.

Force yourself to adapt!

Decide what you're going to do and *set a deadline* for its completion: Begin with an easy project and do the best you can to complete it. That way, whether you have a good result or a bad result, at least you will have finished something. Having a deadline keeps you from drifting around for days and going crazy with small details that make the process too long. Usually, people start playing around with the software without a definite purpose in mind. This will give you a random output rather than a specific result. It won't motivate you and will give you the impression that you can't use this software.

Instead, if you *propose a simple project*, you have a goal to work toward and this will allow you to find and master the tools you need to achieve that goal. Once you finish your project, even if it's not perfect, you will have learned to use some tools and will have a completed project to show for your efforts. This will ultimately motivate you to improve your skills next time with a more complex project that will require you to explore and learn about additional Blender tools.

Keep in mind that the key here is to start learning little by little, taking small steps to keep you motivated. If you start with a large, complex project that involves a lot of different steps, you may encounter problems at some point that will frustrate you. When you work on something small, even if you run into difficulties and the final result isn't perfect, you don't have that much time invested in it, so a less-than-perfect result won't be a big issue. Over time, as you complete a few of these little projects in Blender, you'll have acquired a knowledge base and will understand how the new software works; at that point, you can judge if you're interested in learning more or if you are more comfortable with other software you've used.

There are many types of animation software available and each one is different, so depending on your work, your style, your taste, and your personality, you may prefer one over the other. What is intuitive and comfortable for some people may not be for others. However, if you give this new software a good test drive, maybe you'll encounter some challenges, but you'll also find features you didn't know about that are really cool. In my case, I was very comfortable with 3ds Max, but after trying Blender extensively for a few days (Yes, only a few days—it was very intense, though!), I honestly couldn't go back. Of course, I missed a few tools but, on the other hand, I found Blender's advantages clearly worth it (in my case, anyway), so I've been using it ever since.

I hope this motivates you and encourages you to actually try Blender and give it a chance instead of just opening it and deciding you don't like it because you can't master it in 5 minutes. (I'll bet you didn't master any other software in the first 5 minutes either!) The keys to success with learning a new software are to *develop a project with a feasible goal, set a deadline, and try your best to make it happen!* No excuses, no complaints! Discipline and perseverance are critical elements to your success. While these tips are just guidelines and describe the method I use every time I need to learn new software, it may not be that useful for you or you may find a better approach. But if you don't know where to start and feel discouraged, just try it!

How to Use This Book

This book is divided into five parts to help you to keep track of your progress:

- **Part I, The Basics of Blender (Chapters 1, 2, and 3):** These first chapters will help you understand Blender's features and tools so you can create your first basic scene with it.
- **Part II, Beginning a Project (Chapters 4 and 5):** Before you start any project, you'll need to do some preparation work and start with a design.
- **Part III, Modeling in Blender (Chapters 6 and 7):** You'll learn how to use Blender modeling tools to create a 3D character.
- **Part IV, Unwrapping, Painting, and Shading (Chapters 8, 9, and 10):** In these chapters, you'll learn all the steps to add color and create textures that will improve and define your character's looks.
- **Part V, Bringing Your Character to Life (Chapters 11 and 12):** Creating a skeleton that deforms your 3D character can be tricky. In these chapters, you'll see how to make a skeleton work properly and you'll finally make your character move.
- **Part VI, Getting the Final Result (Chapters 13, 14, and 15):** Once your character can walk, you'll composite it into a real video. For that, you'll need to use Blender's camera tracking tools and compositing nodes. Also, in the last chapter, we'll discuss some additional Blender features and tools.

Of course, you can skip to the parts of the book you're most interested in, but if you're new to Blender, it's recommended that you start from the beginning so you can understand the software before you start with something as complex as the creation of a 3D character. However, if you're already familiar with Blender, you can go ahead and skip the first three chapters and start learning about character creation.

In each chapter, if some basic knowledge is required, I explain it before diving into the real step-by-step process. You'll also find tips and useful shortcuts along the way to help you work faster and more efficiently!

Chapter 1, What You Need to Know about Blender, describes this open-source 3D animation software, the history of its development process, and how it is funded. You don't really need to know this information in order to use Blender, but it's quite interesting and it will give you an overview of some of Blender's strong points and how the software evolved.

Chapter 2, Blender Basics: The User Interface, takes you through the user interface, basic navigation, selection tools, and Blender's innovative nonoverlapping windows system.

In Chapter 3, Your First Scene in Blender, you'll learn how to create a very basic scene that lets you play with the main tools, simple modeling, materials, and lighting. You'll also learn the differences between rendering with Blender Render and Cycles.

After this introduction, you'll start the main project: creating a 3D character. Chapter 4 explains everything you'll need and discusses preproduction and how to get ready

for any project. You'll learn that preparation is essential! The reason why I chose to create a character as a project for this book is because this process requires you to use almost every feature of the software to complete the project: modeling, texturing, rigging, animation, rendering, and compositing.

In Chapter 5, you'll learn the character design process. Making some sketches before you start working in 3D is very useful, so when you jump into Blender, you'll have a clear idea of what you want to create.

Chapters 6 and 7 cover Blender 3D modeling tools and the step-by-step process of modeling a character.

In Chapters 8, 9, and 10, you'll unwrap the character, create textures to add some color to your 3D model, and then apply materials to control how the light affects the model's surfaces.

In Chapter 11, I describe rigging, the process of creating a skeleton that deforms the character model and provides you with the controls to pose and move the character intuitively.

Chapter 12 covers animation. You'll learn about the basic animation tools in Blender and make your character walk.

In Chapters 13 and 14, you'll see how to track the camera of a real video and composite your character into a scene, so that you end up with something cool to show your friends, rather than just a character inside Blender.

Chapter 15 concludes the book and describes some additional features of Blender, such as dynamic simulations, particles, and smoke and fire, so that you get an idea of some additional features that Blender provides.

Supplemental Material

Of course, I encourage you to develop your own creations from scratch and to use your own video to track the camera, but if you prefer to follow the book step by step (with the same materials that are used in the book), or if you may want to skip some parts of the book, you'll find all the material you'll need to start from any point in the book in the ancillary materials on the companion website: informit.com/title/9780133886177.

- Blend files with different character-creation levels of progress
- Texture images for the character
- Real video for camera tracking
- Final results files
- Video tutorials for some parts of the book
- PDF of a Blender keyboard shortcut reference

With no more hesitation . . . let's start learning!

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Special thanks to the *Luke's Escape* team, which I'm honored to be a part of, as the image featured in this book's cover is the result of their work for the short film that they allowed me to use here. Thank you!

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About the Author

Oliver Villar, born in Galicia, Spain, in 1987, has been drawing since he was a kid. His interest in art brought him into 3D, which he's been studying since 2004. He used different commercial 3D software before discovering Blender in 2008. Since then, he has used Blender professionally as a 3D designer and tutor. In 2010, he funded blendtuts.com, a website devoted to offering quality Blender training videos to the community. Currently, he's working as the co-director of *Luke's Escape*, a 3D animated short film made with Blender.

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Learning Blender Ancillaries

Here is a list of the bonus resources available to you. You can download the files from the companion website: informit.com/title/9780133886177. Click the Register Your Product link to gain access to the content.

These videos show the result of the project you will create (making an animated 3D character and integrating it with a real video) in two different resolutions (HD and Full HD).

Project Result 720p.mp4 (HD)

Project Result 1080p.mp4 (Full HD)

Video tutorials (Blender Video tutorials help you get started with Blender and cover in a more visual way some of the topics explained in the book. Total Running Time: 5+ Hours):

- 01_Blender's Interface.mp4
- 02_3D Navigation.mp4
- 03_User Preferences.mp4
- 04_Selections.mp4
- 05_Object Manipulation.mp4
- 06_Your First Scene.mp4
- 07_Your First Render (Blender Render).mp4
- 08_Your First Render (Cycles).mp4
- 09_Modeling Basics I.mp4
- 10_Modeling Basics II.mp4
- 11_Modeling a Face.mp4
- 12_Rigging a Leg.mp4
- 13_Skinning.mp4
- 14_Facial Rig.mp4
- 15_Camera Tracking.mp4
- 16_Compositing.mp4

Blender Files (character-creation Blender files at different stages of the process so readers can analyze them or start to work at any point of the book, without having to start from scratch):

- 01_eyeball.blend
- 02_eyeballs.blend

03_face_model.blend
04_torso_model.blend
05_legs_model.blend
06_boots_model.blend
07_hands_model.blend
08_cap_model.blend
09_hair_model.blend
10_details_model.blend
11_unwrapping.blend
12_texturing.blend
13_shading_bi.blend
13_shading_cycles.blend
14_skeleton_bi.blend
14_skeleton_cycles.blend
15_skinning_bi.blend
15_skinning_cycles.blend
16_jim_final_rig_bi.blend
16_jim_final_rig_cycles.blend
17_walk_animation_bi.blend
17_walk_animation_cycles.blend
18_camera_tracking_bi.blend
18_camera_tracking_cycles.blend
19_compositing_bi.blend
19_compositing_cycles.blend
jim_cool_animation_example.blend

Resources (designs, reference images, textures, and real video):

01_Character Designs:

01_Sketches:

Body Sketches.jpg
Color Tests.jpg
Final Silhouettes.jpg
Head Sketches.jpg
Refined Design.jpg
Rough Design.jpg
Silhouettes.jpg

02_References:

Body Back Reference.jpg
Body Front Reference.jpg
Body Size Reference.jpg
Head Back Reference.jpg

Head Front Reference.jpg

Head Side Reference.jpg

Body Views.jpg

Face Views.jpg

02_Character Textures:

base_texture.png

jim_diffuse.png

jim_hardness.png

jim_roughness.png

jim_specular.png

jim_textures.psd

uvs.png

03_Footage:

Real Footage.mp4

Extras:

Jim Illustration Time-Lapse.mp4

Jim Illustration.jpeg

Blender Keyboard Shortcuts Reference.pdf

Blender Keyboard Shortcuts Reference.jpg

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Project Overview

Every project has different steps you need to follow in order to be successful. The order in which you proceed through the steps to reach the final result can be called the “workflow” or “pipeline.” In this chapter, you’ll learn about the process you will follow throughout the rest of the book to create a character from scratch. You’ll gain basic knowledge about how you can divide any project into stages and execute it. In the next section, you’ll learn about the three main stages that a project goes through.

The Three Stages of a Project

Usually, any project in 3D, graphics, or video goes through three different stages: preproduction, production, and postproduction.

Preproduction

Preproduction is everything that happens before the actual production of a project, such as preliminary sketches, ideas, designs, and planning. It’s probably the most crucial stage of any project, and a lot of amateur projects fail because of the lack of good preproduction. (Some projects don’t have any preproduction at all!)

When you plan and organize what you will need to do to complete a project, chances are you’re going to be better prepared for what’s to come. If you skip preproduction and jump right into production because you can’t wait to see the results, you’ll likely encounter unexpected problems and issues you didn’t anticipate. You’ll have to redo a lot of work and lose lots of time or, in the worst-case scenario, you’ll give up.

Good planning allows you to anticipate any possible problems before they actually happen and this way you can prevent them from occurring. If you run into something you don’t know how to do, you can make some quick, basic tests to find a solution *before* you get far enough into the project to discover that it doesn’t work.

As a result of this preparation, the actual work during production will be a lot faster, easier, and straight to the point, as you’ll already know how to proceed. Keep in mind

that even with a good preproduction stage, you will still run into issues. This is how it goes, but at least a lot of those issues will be handled before they become bigger problems, so the more preparation, the better.

There is another important advantage to preproduction: it can motivate you during the production stage. When you think about everything you'll have to do and then define the process step by step, it suddenly gets easier because you don't have a *big* project before you, but instead you have a list of small and manageable tasks. You'll go through this list, keeping track of your progress, and you'll always know what you have done so far, what you still need to do, and what may be missing.

There is a popular phrase that sums up preproduction pretty well: "*Think twice, work half.*" A great result doesn't come from working harder, but from working more efficiently. You need to think of efficient ways to work. Usually, you'll discover them only after you've done something wrong, but that's when you learn and gain valuable experience!

Production

Once you have everything planned for a project, it's time to start with the actual job, which is production. In a movie, for example, production would be the stage of the project in which the sets are built and the scenes are filmed with the actors and props in place as planned during preproduction. Thorough preproduction will help you complete production more easily and in a more straightforward process.

Production is probably the hardest stage of a project because it's the point of no return. After production is completed, it's very difficult to change things. Let's say you're building a house; during preproduction, it's very easy to change the design of the house using a computer or an architectural drawing, but it's really difficult and time-consuming to make changes once the walls are in place!

That's why preproduction is crucial: it helps you make sure you're not going to make mistakes while you're developing the final product. Production is difficult enough; there are a lot of challenges and it's impossible to predict every possible problem that might arise until you're actually making the product, so any preparations you can make to smooth out the process helps a lot.

Postproduction

Postproduction is everything that happens between production and the final result. It's like putting the finishing touches on a new house with details such as painting the walls and adding interior decoration. In a movie, it would be the stage in the process in which you add the final visual effects and retouch what was filmed during production.

Depending on the project, postproduction can be easy or hard, simple or complex, and it can involve just minor details or something really important. Postproduction is when you actually decide how the finished project will look.

Suppose you film two actors having a conversation inside a room. During postproduction, you can color correct the scene, switch it from day to night, change what will

be seen through a window, blur things out, zoom in, or even add a new character! The possibilities are endless and they will define what people will see when you release your image, video, film, or whatever your project may be.

Defining the Stages

Now you know the three main stages that a project goes through, but it's very important to know where each stage ends and the next one starts, as each project is different. Let's study some examples to understand these differences better.

A Film without Visual Effects

Today, almost every single film has some visual effects. However, let's consider a film that doesn't have any visual effects. This will help you understand the basic process of film production, and then we'll discuss some different production options.

Note

Remember that visual effects are not just explosions, spaceships, aliens, or monsters. There are a lot of visual effects (commonly referred to as invisible effects) that are much more subtle and you may not notice them while you're watching a film. Set-extensions, background replacements or set cleaning, for example, are present in almost every single movie you watch and they are also visual effects.

During preproduction, the filmmakers create the film's script and decide what will be the climax moments (and maybe even film them to test whether they really work). Every film goes through storyboarding, the process of making quick drawings to define where the cameras will be positioned and what will happen on each shot, so the production team can plan each shot, see what they'll need on set, know what type of lenses to use in the camera, and identify where the actors will be positioned. Then, the filmmakers search for the locations where they're going to film the scenes. They also have to create the costumes the actors will wear and all the props they'll have to interact with. Then the filmmakers cast the actors and all of the extras who will appear in the film. Finally, the filmmakers must assemble the technicians who will film the movie and manage all the equipment, build the sets, and so forth. Usually, composers begin to develop the music at this stage so that a rough edit of the film can be made using the storyboard and the timing of each shot can be defined.

Everything is now ready to start filming, so production begins. At this point, the actors already know the script and the team knows what they need to do on each shot and what has to appear on camera. Production is usually not a very long process; because all aspects of the project were organized during preproduction, the production stage (the most expensive stage) is as short as possible. When production is completed, the movie has been filmed according to the decisions made during preproduction about where, when, how, and with whom.

Once filming is completed, postproduction can begin. The film must be edited at this point, perhaps by using some color correction to make a scene look more vivid, warm, or cold, depending on the feeling the director wants each scene to convey to the audience. Perhaps the director decides that a shot would work better if the main actor's face were closer, so the video editor zooms in a little. Suppose the name of a business appears in the background and the director doesn't want it to be recognizable; some simple visual effects can remove it or replace it with the name of another business that will pay the filmmakers for advertising! This is the point at which the last retouches are added to the film, the complete soundtrack and all the sound effects are included, and the final result is achieved.

A Visual Effects Film

Let's now analyze the differences that a film with complex visual effects would have compared to the previous example.

During preproduction, the production team would need to think about what visual effects to use, how they're going to be filmed, and what will be required to create them. Generally, the visual effects team works very closely with the director during preproduction to see what's possible, what's not possible, and how the effects will be achieved. (Usually, almost anything is possible in visual effects; it just may be way too expensive for a particular film's budget.)

During production, the visual effects team may need to film some shots in special ways, using green screens or using markers or puppets the actors can interact with so that later the team can add an animated character to that scene. Lighting in the sets has to be measured and recorded, so the team can simulate it later in the 3D world to make it match the lighting on the real set. Some effects like explosions may need to be filmed separately so they can later be integrated with the footage of the actors.

After the movie has been filmed, it's time to begin the postproduction stage, but because this film involves visual effects, the line between production and postproduction tends to blur and sometimes these stages actually overlap. The visual effects artists probably work on some shots even before production begins so that during filming, all the different elements that comprise a scene will fit together seamlessly.

The visual effects team has its own preproduction, production, and postproduction stages. They plan the specific effects and determine how a shot will be accomplished; then they proceed to production and work to create the elements of the visual effects, and finally combine those elements, adjusting colors, shapes, textures, and so forth.

An Animated Film

The stages of an animated film are even more difficult to distinguish, as the entire film is computer-generated, the line between production and postproduction is not so clear.

During preproduction, all aspects of the film are planned and designed as usual, but then production and postproduction tend to overlap because every aspect of these stages happens in the 3D software. Usually, it's easier to divide the stages, with

production creating the action (developing characters, sets, and animation), and post-production creating the effects such as water, splashes, particles, cloth, dust, smoke, fire, explosions and other simulations. Then, the final compositing will bring all these diverse elements together.

A Photograph

Yes, even something as simple as a photograph can be divided into the three production stages. Even if photographers are not conscious of it, they're performing the stages of production with their own photos.

First, photographers complete the preproduction stage by thinking about what they're going to shoot and where. During production, they must go to the location, pose the subject, and finally take the photo. Then, even using a smart phone, they can do some postproduction work such as adding an aging effect to the photo, or increasing its contrast, or maybe even changing it to black and white.

A Character-Creation Plan

Now that you have a better understanding about the three main stages of a project, let's define the process you'll follow throughout the remainder of this book to create a complete 3D-animated character.

Preproduction

A character-creation process starts, of course, with a character design.

- **Designing:** Make some drawings to define what the character will look like, what clothes it will wear, and what features might suggest its personality.

Production

This stage can be rather complex and extensive because it's the main part of the process in which you go from the design to the completed character.

- **Modeling:** Model the 3D character in Blender following the design you created in the preproduction stage.
- **Unwrapping:** Turn the 3D model into a two-dimensional mesh internally so you can project a 2D image texture on it.
- **Texturing:** Paint the textures for the various aspects of the 3D model's surface, such as clothing textures, skin, hair color, and so forth.
- **Shading:** Take texturing a step further by creating materials that will define the surface properties of your character, such as how reflective or shiny they will be, or whether they will be rough or smooth.

- **Rigging:** Add a skeleton to your character and define how it will work and how it will control the character.
- **Animating:** Pose the character using keyframes at different times of an animation to make the character perform an action such as walking or running.
- **Video recording:** Record a video into which you'll place your character later.

Postproduction

Once the character is finished, there is still some work to do to make it look pleasing or to put it into a scene.

- **Camera tracking:** Simulate a camera's tracking in the actual footage you record so you end up with a camera in the 3D world that will move similarly to a real camera and allow you to insert 3D elements into your video.
- **Lighting:** Add lighting to your scene to make the lights and shadows fit the video you recorded during the production phase. The addition of lighting is usually part of the production stage, but because this project's main goal is the creation of a character, this time lighting will be part of postproduction.
- **Rendering:** Convert the 3D scene into a 2D image with shadows and lighting.
- **Compositing:** Take the video and the 3D objects, combine them, and make any necessary adjustments to them so they fit together and look realistic.

Summary

Now you have an idea of the process you're going to go through to create your own animated character and you understand the three main stages of every project. Preproduction is especially important and you have to keep that in mind for future projects. A lot of people fail even after significant planning and preparation, so imagine the probability of failing if you don't make thoughtful preparations and design choices in preproduction. Almost every professional 3D artist has gone through this process and understands the importance of preparing and organizing projects beforehand. Take advantage of learning from their experiences!

Now you're ready to start working on the actual project!

Exercises

1. Take any movie that you like and imagine how it would be divided into preproduction, production, and postproduction.
2. Have you ever had a project fail? Analyze where you failed and think about how you'd do the project differently using the three stages discussed in this chapter.

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