To my three angels…
Brittany, Nastasia, and Sofia
with all my love.
Acknowledgments

I would like to begin by giving special thanks to my good friend William Vaughan. William is, by far, the most talented artist I’ve ever met. We share a common kinship—a love and passion for teaching the arts we ourselves love. William was kind enough to recommend to Pearson that I write this book, make the introduction, and then even come on board to handle the technical editing. I am always delighted by how insightful he is and by the straightforward, pull-no-punches honesty that we have with one another. I will always look forward to an opportunity to work alongside Will. This book would not have been possible without him.

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And last but not at all least, I dedicate this book to my mom who has always been my biggest supporter and champion. I love you, Mom!
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Foreword

Since ancient times, magic has been a common source of entertainment. Magic is the act of entertaining an audience using tricks to create illusions of the impossible using natural means. An artist who performs magic is often called a magician or an illusionist, which has led me to think of visual effects artists as digital illusionists.

Visual effects artists have taken illusions to previously unimaginable places over the years and have carried on the legacy of the many illusionists who went before them. One attribute that separates a traditional illusionist from his digital counterpart is secrecy. Whereas traditional magicians kept secrets to preserve the mystery of their tricks, the best visual effects artists I know are quick to break down their digital illusions and share them not only with other VFX artists, but the audiences as well.

My career has afforded me the opportunity to work with many of these talented VFX artists over the years, both in productions and in the classroom. To produce digital illusions, VFX artists’ primary skill is problem solving. Visual effects instructors must attain high levels of problem-solving ability, but they must also acquire the ability to pass their knowledge onto others. Finding a VFX instructor is easy. Finding a great instructor with the ability to inspire and create production-ready artists with the needed skills often feels like a magic trick of its own.

Jon Gress is among the rare breed of VFX artists who can move seamlessly between problem solving on a production and imparting his experience in the classroom. To truly appreciate Jon as a VFX artist, you have to see him in action during a production. I first met him ten years ago while he was directing the award-winning, live-action, visual effects-heavy student short film NASA Seals. I walked into the studio during the last few weeks of production and witnessed what looked to be chaos and a production that was out of control. It turns out, it was orchestrated chaos.

At the time, Jon was filming a few greenscreen pick-up shots of an actor floating off into space, directing artists working on several digital destruction shots, and fine-tuning the edit, among other things. It was fun watching how trivial he made the whole process look and how he effortlessly motivated the team of artists, even at the 11th hour of production, when most teams would be discouraged. It’s no real surprise that some of those artists went on to
work at studios like Digital Domain, WETA Digital, Zoic, Pixomondo, The Asylum, Cinesite, Prime Focus, and Walt Disney Animation Studios.

A couple years later, I recommended that the Digital Animation and Visual Effects School at Universal Studios hire Jon as the VFX instructor. The school was in the process of retooling its curriculum and needed someone with Jon’s experience to come in and help enhance the training the school was providing. Shortly after Jon came on board, the quality of the work being produced by the students increased exponentially. More importantly, the students had a newfound love of the art of visual effects.

Jon brings a contagious energy to anything he is involved with, and he is passionate about the craft of filmmaking. Couple that with his hands-on experience with and knowledge of VFX and his ability to problem-solve and you have the skillset needed to train the next generation of digital artists.

Over the years, Jon has helped to keep movie magic alive and thriving by training hundreds of artists who have gone on to work on everything from summer blockbuster feature films to award-winning television series, and more.

When I heard that Jon was going to be writing a book on visual effects, I was excited that his knowledge would finally be bottled and find its way into the hands of more artists.

Throughout the pages of this book, Jon introduces you to the magic of visual effects and imparts his knowledge so that you can create your own digital illusions. Your audience will walk away knowing that what they saw couldn’t have been real—but they will still believe.

—William Vaughan, Academic Director, Digital Animation and Visual Effects School
Introduction

Over the past 20 plus years, I’ve done just about every job imaginable in the worlds of movies, TV, radio, and music—from writing, producing, directing, and visual effects supervising to cinematography, recording, and even performing. I’m one of those fortunate people who has always just known what they wanted to do… make movies.

I made my first “film” at four years old (see Figure 1) by hijacking my father’s 8mm film camera and sneaking outside to surreptitiously film the gardener. It was by no means an epic, but even at that young age, I was already fascinated with movies. I had been bitten by the bug that early filmmakers called silver addiction (so named because of the filmmaking obsession that required expensive silver halide-based film stocks and processing the love and need to make movies. I knew, even from early childhood, that I wanted to be on the cutting edge of any new technology that could bring any vision imaginable onto the silver screen and into reality.
By the time I was writing, producing, and directing my own productions, I found that I needed to constantly, and quickly, be able to bring the people working with me up to speed using these advanced technologies in order for them to be able to effectively help me work on these quests (and they were truly quests). It wasn’t long, after repeating these little training sessions over and over, before I began formalizing this “film/VFX crash course” into a complete, concrete, teachable curriculum that I then refined, again and again, over the next decade or so. Eventually, I was formally teaching hundreds of visual effects (VFX) artists who, as a result of this material, are now successfully working at virtually every major visual effects company around the world. This curriculum had evolved into perhaps the fastest and most complete curriculum for becoming a competent and professional visual effects artist.

So that is what this book is: decades of production experience and more than ten years of refined teaching (training real-world visual effects artists—some with absolutely no experience at all), distilled into one book you can use to go after your dream of creating VFX and the movies you want to work on.

My Promise to You

I despise fluff, especially when it comes to training materials. Anyone who has read a training book, watched a video training tutorial, or sat through a seminar knows what I am talking about. That moment you heard the ninth regurgitation of a simple example or concept… after you’ve lost count of the never-ending ummms and uhhhs… the point after you’ve contemplated methods of escape from a presenter’s incessant slurping, nervous coughing, monotone blathering, or pointless passage… that moment you realize, “Why am I sitting here for this??! This could have been explained in one simple sentence! Hours ago!” Why is [the presenter] still endlessly drudging on about the same thing??!” Well, I agree with you. In fact, that is the entire premise and reason I am writing this book. I’m just like you. I can’t tell you how many times I’ve exclaimed, “Get on with it already!” while reading training materials or watching a training lecture or video.
My promise to you, as one who can empathize, is that I will present to you, in as streamlined and concise a manner as possible, everything I can to make you an excellent VFX artist with no fluff.

**What to Expect from This Book**

If I do present something that might seem like fluff, be assured, it isn’t. Any example or information I include related to film, video, art, history, and so on, or something that might seem to be extraneous, has been carefully selected and is included for a very precise and practical purpose. Usually, it is because the example is one of the earliest, and thus easiest to understand, and can form the basis for a very complex concept I cover later in the book.

I have taken a lot of artistic license with some of the scientific and technical information I will reveal and present to you in this book. Years of teaching these concepts and techniques have allowed me to refine them into very distilled forms that are easy to understand, relate to, and remember. I’ve even distilled some technical information into a “not so perfectly scientifically accurate” form, but one that makes sense to those of us with less-than-alien-sized heads who aspire to be excellent VFX artists, not engineers.

It is my opinion that what is crucial to being a good VFX artist is that you have a solid comprehension of the concepts and techniques of film and visual effects, and that you do not necessarily have to know every bit of science behind it or software button to be pushed. I would guess that you probably have no clue as to what the precise spark plug gap measurements are in your car or how to set them, yet you are able to drive perfectly fine. That is why I take a software-agnostic approach wherever possible, unless I am teaching a particular application or making comparisons between applications.

By the time you finish carefully reading this book, you will know most of what you need to know to accomplish virtually any visual effect you can think of. At the very least, you’ll know how to proceed to accomplish any effect. Understand, knowing is only half of the equation. Actual doing must take place as well. With practice and perseverance, I have no doubt you will become the visual effects artist you aspire to be.

**Special Features of This Book**

But that’s not all. This is not your ordinary book. Oh, not at all. Read on to find out about some of its hidden gems.
Downloading Files to Use as You Follow Along

I created numerous VFX and other image/movie files to use as examples in this book. I’ve made many of them available to you for download from the Peachpit website. This way, you can work alongside me, using many of the same files you see in the book’s figures.

All you have to do is go to www.peachpit.com/register and follow the instructions for registering this book. After that, a download link will appear, and you can follow that link to retrieve your files.

Aurasma Augmented Reality–Enabled Features

Download the Aurasma augmented-reality (AR) app for your iPhone or Android device, do a search for visual effects, and then “follow” the channel that has the picture of the cover of this book.

Open the Aurasma AR viewer, point it at the cover of this book (whether the physical book on your bookshelf or even an image of it that you may come across online), and watch the cover image come to life with a dazzling preview of what’s inside the book.

One of the amazing benefits of all of these great new technologies I work with is that I am able to continue to extend the features of this book far past the print version. From time to time, I will post augmented-reality updates to this book to add new tips, tricks, examples, and other amazing new content. I will list these on my website at: http://jongress.com/vfxbook/AR. To use these new updates, just open the book to the page and image listed in the AR Update, open the Aurasma app, and point your device’s camera at the image to see the amazing new AR features.

Stereoscopic 3D Features

Chapter 14 is an entire crash course in stereoscopic 3D creation. To best experience the examples, you will need a common pair of 3D red/cyan glasses. If you don’t have a pair of these handy, you can easily find them for around a dollar online by doing a simple web search for paper 3D glasses. These cheap paper ones work just fine, but if you plan on doing more extensive stereoscopic 3D work, I recommend that you invest in a pair of more durable plastic ones. If you have trouble finding them, head on over to my website at http://jongress.com/vfxbook/3dglasses and I’ll be happy to send you a pair for free (if you just cover the shipping).
But if you’re so excited to get started that you just can’t wait and you need a pair right now, Chapter 14 includes a make-your-own, guerrilla-style DIY method for creating a pair of 3D glasses in a pinch, using commonly found items; you can use these until your real pair arrives.

**Extended and Bonus Features**

Since I am constantly developing new concepts, techniques, and technologies, in addition to the AR and 3D content, from time to time I will also add new tips, tricks, techniques, and info about breaking technologies and more to the book. Check in now and then at the book’s website at www.peachpit.com/store/digital-visual-effects-and-compositing-9780321984388 and my website at http://jongress.com/vfxbook.

**How to Use This Book**

This book (and accompanying materials) has been refined over my many years of teaching hundreds of Hollywood visual effects artists (Figure 2), to be a complete VFX course and reference. It is designed to take you from your current level of knowledge (whether you are a total VFX novice or have some knowledge already), to a professional level of understanding all the principles, skills, and techniques, from foundations and basics to the cutting edge of working as a professional VFX artist, in the fastest time possible.

Each chapter builds upon the previous chapter, so your best bet is to read the chapters in order to gain the maximum benefit and then use the book as your go-to reference thereafter.

You may be tempted to skim through Chapter 1, which, in the lecture series I do, is affectionately called “Hell Week” by those I train, owing to the overwhelming and intense amount of technical information that I like to get out of the way as quickly as possible—typically in a week. Nevertheless, I highly recommend reading Chapter 1 in full. It’s not critical that you fully comprehend, memorize, or even retain all the information in Chapter 1, but you should try to assimilate as much as you can. By simply being exposed to the information, you will undoubtedly retain much of it by osmosis.
I present much of my material in what I like to refer to as “Miyagi-style” (referring to the character in the movie Karate Kid). Mr. Miyagi teaches his student very effective skills, without the student even realizing he’s being taught, through a series of simple, seemingly irrelevant lessons. So many important jewels of knowledge are hidden in the form of analogies, short, true-life production stories, and even simple or seemingly not-so-important skills. Remember my promise… everything in this book is relevant. Like Neo in The Matrix, you will catch yourself realizing, “Whoa! I know Kung Fu!” (In Chinese, the term kung fu (功夫) refers to any skill that is acquired through learning or practice.)

So without further ado… plug yourself in to the matrix… let’s roll!
3D for VFX

VFX have advanced tremendously since their humble stage beginnings as practical special effects in the late 1800s and early 1900s. With the rapid advancements in computer graphics technologies and techniques in the late 1990s and early 2000s, those models, miniatures, and puppets rapidly gave way to the world of 3D CGI (computer-generated imagery). In 3D, anything can be created—from props and digital prosthetics to entire sets and even full 3D worlds.

How 3D CGI Is Created

At the heart of 3D CGI is the concept of representing the 3D world on a 2D screen. To do this, computer software must somehow calculate and simulate points in space in the 3D world in order to draw (or render) points (also known as vertices) and surfaces (whether polygons, surfaces, normal vectors, also called normals, or faces). We VFX artists use a common mathematical 3-axis system to describe our virtual 3D world.

We call this the XYZ coordinate system. Typically X represents the horizontal axis, Y represents the vertical axis, and Z represents the in and out or depth axis. If you are unfamiliar with the XYZ coordinate system, an easy way to remember it is to hold your fingers like a child pretending to shoot a gun, but with your middle finger sticking out at a 90 degree angle (perpendicular) to your pointer finger, as seen in Figure 4.1. With your fingers in this configuration, as silly as it might look to those around you, your middle finger is the X axis, your thumb is the Y axis, and your pointer is the Z axis.

![Figure 4.1](image_url)  
Fingers representing the XYZ coordinate system: middle finger (X), thumb (Y), and pointer (Z)
There are a few different methods of creating 3D models, or meshes, but they all work pretty much the same way.

Points (vertices) or curves (also known as splines) are created or placed in the virtual 3D environment (see Figure 4.2). These points or curves are then connected to create edges (Figure 4.3). Edges and splines are then closed to create polygonal faces (sometimes referred to as patches), as shown in Figure 4.4.

Primitive 3D shapes can also be created, modified, and combined to more quickly create complex objects, as shown in Figure 4.5.

For creating hard surface models such as buildings, furniture, computers, and so on, this method of building 3D models works very well. In cases where more curved or fluid shapes are required (called organic modeling), rough or blocky polygonal models’ faces, as shown in Figure 4.6, can be smoothed (or subdivided) to create even more complex shapes and models. This method of creating rough blocky polygonal models and then subdividing them into smooth organic shapes is referred to as subdivision surface modeling.
[Figure 4.3] Vertices and splines connected with edges

[Figure 4.4] Edges and splines closed to create polygonal faces
Figure 4.5] Primitives combined to create complex meshes

Figure 4.6] A simple untextured/unsurfaced 3D polygonal sphere
Once faces, or polygons, are created, they can be textured (or surfaced) to create the appearance of real or fictional objects. These textures (or maps) can be any combination of colors, images, or mathematical procedural operations, as discussed in Chapter 2 in the section “Other Matched Texture/Layer/Element Sets.” Textures can then be layered and combined to form complex materials (or shaders).

Texturing (or surfacing) is both an art and a science. The most important skill required for great texturing or surfacing is refining your observational skills. Let’s take a look at a couple examples.

In Figure 4.6 you can see a simple 3D sphere.

By carefully observing the details and attributes of the surfaces of other spherical-based objects, you can easily modify the textures and surface attributes of this simple sphere, changing it into many completely different objects.

First, for a simple one, let’s create the texture of a billiard ball. Billiard balls are colored and have a high-gloss finish. By setting the value in the color channel—in this case, to blue—and the diffuse channel to 90% (which will give the ball 90% of its reflected color from the blue base color in the color channel), the ball will take on a nice, bright, saturated blue finish (as seen in Figure 4.7).

Because a billiard ball is also very shiny from the highly polished finish, you want to turn the specular value up very high as well (in Figure 4.8, the specular channel is set to 100%).

Notice that the specular highlight, or hotspot (the white spot reflection of the light source), is very broad and spread out. The tight molecular structure of a billiard ball’s high-polish finish creates a very tight highlight spot. To simulate this, you can also increase the glossiness channel to 100%, as shown in Figure 4.9.

**[Figure 4.7]** 3D sphere with Blue selected in the color channel and the diffuse channel set to 90%

**[Figure 4.8]** Specular channel set to 100%

**[Figure 4.9]** Glossiness set to 100%

[Note] Although every 3D application has a slightly different approach to texturing/surfacing, the core concepts are identical and ubiquitous among all 3D applications.
That gloss finish means that it is partially reflective. So you can also add a slight amount of reflectivity to the reflection channel, which gives a nice re-creation of a billiard ball’s texture. Of course, for a production, as discussed in Chapter 2, you would want to add the number decal and many imperfections to the surfaces, such as dings and dents in the finish and even chalk marks and fingerprints to dull down the finish in some areas for added realism.

Next, let’s look at the mirrored gazing ball reference image in Figure 4.10.

From the very first glance you can see that the gazing ball really has no color of its own, but instead, because it is so highly reflective, it gets its color from the reflection of whatever is around it—in this case an outside park scene. By turning the diffuse map to black (or zero), you turn off any base color the sphere would have. You can also set the color map to black since there isn’t any. It too is shiny and glossy, so those aspects should be set high, similar to the way they were set for the billiard ball. Finally, you will want to set the reflection channel to 100% (or close to it) since a mirrored ball is definitely reflective. But something’s wrong! So far your sphere is just a shiny, glossy black. Actually, the only thing that’s wrong is that there’s nothing for your mirrored ball to reflect. When you load the image of the exterior park scene (Figure 4.11) where the reference image was taken into the environment or reflection channel, the 3D mirrored ball instantly springs to life, as you can see in Figure 4.12.

Now the ball has become a very accurate re-creation of the original. As with the first example, for a production quality model you would want to add all of the similar “reality imperfections.”
Finally, for a completely different spin, let’s create a pumpkin. We’ll push in the top and bottom of the sphere and reset all of the map parameters; then, using the same technique and dirty warehouse floor texture we used in Chapter 2, we’ll create a dirty, desaturated orange texture (Figure 4.13).

Next, since a pumpkin reflects a lot of its own orange color, set the diffuse channel high, to about 80% (to taste of course), the specular channel to about 20% (to give a wide highlight), and the glossiness to between 30 and 40% to emulate the shiny waxy-like surface of a pumpkin. This will give you something that looks like Figure 4.14.

It’s always important to think about a texture or material thoroughly, the same way you thoroughly need to think through every VFX you create, as described in Chapter 1. If a pumpkin were to have the dirty discolorations that the dirty warehouse floor texture has, it most definitely wouldn’t be as shiny on those spots as on the waxy orange surface of the pumpkin skin itself. To simulate this, you can load a matching copy of one of the dirt/grunge textures used to create the orange skin texture into the specular channel to “knock down” the amount of specularity in those spots, as shown in Figure 4.15. This is called specularity breakup.

You can now see that those dirty spots are less shiny than the cleaner skin areas. But this still looks more like a partially deflated dirty orange beach ball than a pumpkin. The magic happens in another channel. This channel isn’t actually a “texture” channel per se in the material/surface sense, but instead, it is a texture channel used by the modeling engine to displace, or push, points/vertices around based on the values of a map (yes, the same kind of map we’ve been using for textures. This one we just need to think through to use for 3D displacement instead of 2D displacement). As with a bump map, a displacement map pushes the vertices in the 3D geometry down, or in, wherever the map is darker and up, or out, wherever it’s lighter.

[Figure 4.13] A dirty desaturated orange texture

[Figure 4.14] The diffuse, specular, and glossiness settings are set.

[Figure 4.15] Specularity breakup added to the specularity (spec) channel

[note] There is no exact science to texturing/surfacing. All of the surface settings described here are starting points and recommendations. Material and texture will always be dependent on the particular model, scene, and requirement and will need to be fine-tuned to taste.
a pumpkin has organic linear stripe-like vertical indentations, a map with wavy dark vertical lines that gradually fade to white and then gradually back into another wavy black line will push the geometry of the sphere in or out at those vertices on the geometry, respectively, based on how dark or light the map is at any given point. Once this map (Figure 4.16) is loaded into the displacement channel, the deflated sphere magically transforms into a natural looking pumpkin! (Figure 4.17)

### 3D Applications

There are many 3D applications, and each has its own strengths, style, workflow, and conventions—but the principles for modeling, texturing, lighting, animating, and rendering are all the same. This section introduces the most widely used 3D applications in the industry.

#### Maya

Originally spawned from Alias | Wavefront’s Power Animator, Autodesk’s Maya (www.autodesk.com), shown in Figure 4.18, is one of the most popular, high-end 3D applications in the VFX industry. Maya has a steep learning curve, but has powerful animating and simulation tools and is almost infinitely extensible with its plugin and customization capabilities.
3ds Max

Autodesk’s 3ds Max (www.autodesk.com) (Figure 4.19) is also part of the Autodesk family of products. 3ds Max has very strong roots in both architectural and gaming 3D but is widely used in many facets of VFX.

LightWave 3D

NewTek’s LightWave 3D (http://newtek.com) (Figure 4.20) spawned from NewTek’s Video Toaster in the early 1990s and, because of its speed, flexibility, and superb renderer, it quickly gained a foothold in television and film VFX, especially in many popular sci-fi series such as Star Trek and Babylon 5.
Cinema 4D

German-based Maxon also released Cinema 4D (www.maxon.net) in the early 1990s (see Figure 4.21). Cinema 4D, though not too popular in those formative years, has quickly grown into a powerhouse 3D application fully capable of stunning 3D and VFX work.

Modo

In the early 2000s, some senior management and developers from NewTek, wanting to take 3D software in a different direction, formed Luxology. Their 3D application, Modo (www.thefoundry.co.uk), shown in Figure 4.22, quickly became a leader and favorite in the industry for its innovative workflow and features.

[Figure 4.21]
Maxon’s Cinema 4D Lite user interface

[Figure 4.22]
Luxology’s Modo user interface
Blender

Originally created by Dutch animation studio NeoGeo and Not a Number (NaN) Technologies as an in-house 3D application in 2002, Blender (www.blender.org) (Figure 4.23) was released as a free and open source 3D computer graphics software product under the GNU General Public License. Blender has been used in many areas of VFX production and continues to develop amazing innovative features—and all for free!

3D Motion Tracking

In Chapter 3, in the discussion of 2D motion tracking, you saw how to track one, two, and even four points on an image to record and utilize the positional/translational, rotational, and apparent scaling data. I say apparent because what we are actually tracking is the points moving closer together, as shown in Figure 4.24, simulating scale, which will sometimes suffice for creating simulated Z-depth movement.

Many times this will be sufficient enough data to allow you to lock your element to the plate so you can create a seamless integration. But what happens if the camera is orbiting around or within a scene, or is moving through a scene at an angle, allowing you to see around objects in the scene as you pass them? New VFX artists frequently want to know the dividing line between
when a 2D track is enough to make a shot work and when a 3D track is required. Well, this is it. Any time the camera *orbits* around or within a scene or translates/passes objects within a scene in Z-depth close enough to reveal the 3D nature of a subject or object (or reveal a portion, or portions, of those objects that weren’t seen originally)—as the examples in Figures 4.25–4.28 illustrate—a 3D track and solution is required.

Unlike 2D tracking, which derives its data from the X and Y motion of pixels on a flat screen, 3D tracking utilizes much more complex triangulation calculations to determine objects’ actual position and motion in 3D space. If you want to be able to integrate a 3D object into a scene where the camera is moving in three dimensions, you need to be able to re-create this camera's motion in 3D and have your virtual camera repeating this same motion in order for your element to integrate seamlessly.

To be really good at 3D tracking (and to avoid the needless frustration many artists encounter), it’s important to understand how 3D tracking works.

The origins of 3D tracking technologies lie in the science of photogrammetry, the scientific method of calculating positions and distances of points referenced
in one or more images. By comparing and triangulating the position of points referenced in multiple images (as seen in Figure 4.29), or consecutive frames of a motion image, the position of those points, as well as that of the camera, can be calculated using trigonometry and geometric projections.

**3D Motion Tracking Application Technique**

A 3D tracker does its mathematical magic in a series of well-defined steps:

1. A mass (usually automated) 2D track, or *auto track*, of the scene is performed, tracking many (sometimes hundreds or thousands) high-contrast *candidate* (or potential) points in the scene. This first track is almost identical to a 2D track except that it is done on a mass scale on the entire image, as shown in Figure 4.30. During this process, complex software algorithms sift through all of the tracked 2D points to weed out and exclude from tracking and calculations.
delete any of those that fall below a user set confidence threshold (meaning how confident the software is that the point being tracked is the same on each frame or range of frames).

2. Next, a complex 3D camera solve is done. A solve is an exhaustive series of calculations wherein the motion of every point tracked is compared and triangulated on a frame-by-frame basis (usually both forward and backward) to determine its position as well as the camera’s position and any movement within each frame, as shown in Figure 4.31. The more information known about the camera used and its motion and environment, the more accurate the solve will be.
3. Once the 3D tracking application completes its solve, it will display the resulting 3D camera, motion track, and point cloud (cluster of points representing solved candidate points). The camera’s position and track, at this point, are relative to the point cloud and not necessarily aligned with the real world X, Y, and Z axes (as shown in Figure 4.32), so the next step is to align, or orient, the scene. Most 3D tracking applications have scene orientation tools that allow you to designate a point in the scene as the X, Y, Z, 0, 0, 0 origin. Additional scene orientation can be refined by using tools that allow you to designate certain points as being on a common plane, or that allow you to manually translate, rotate, and scale the entire scene into position by eye, or by aligning to reference grids, as shown in Figure 4.33.
4. At this point, most 3D tracking applications will allow you to place test objects into the scene to determine how well they follow the track (or stick), as shown in Figure 4.34.

5. If there are any errors or errant motions in the track, you can apply mathematical filters to smooth the tracks motion. Averaging, or Butterworth, filters are common filters to accomplish this. Isolated errors or motions may also be edited or removed manually by editing, adjusting, or deleting track motion keyframes, as shown in Figure 4.35.

6. Once the 3D camera track proves to be solid, the data can then be exported in a variety of file and scene formats to other 3D and/or compositing applications for use.
3D Motion Tracking Applications

There are many 3D motion tracking applications, some which come as integrated solutions in other applications, as well as the standalone application variety. Although their workflows and methodologies vary somewhat, they all contain the steps outlined in the preceding section (whether obviously or under-the-hood in the case of completely automated versions). This section introduces some of the most popular 3D tracking applications.

PFTrack

Originating from the University of Manchester’s Project Icarus, PFTrack (www.thepixelfarm.co.uk) (see Figure 4.36) and its sibling applications have grown into some of the most powerful and widely used 3D tracking applications in the VFX industry.

Boujou

Vicon’s Boujou (www.boujou.com) was one of the first almost fully automated 3D tracking applications and still offers a great set of powerful 3D tracking tools, as shown in Figure 4.37.

Nuke and After Effects

3D tracking has become a commonly integrated feature in compositing applications, which continue to grow and blur the lines between VFX job descriptions. Recently, compositing applications such as The Foundry’s Nuke (www.thefoundry.co.uk) (Figure 4.38) and Adobe’s After Effects (www.adobe.com) (Figure 4.39) have also integrated 3D tracking capabilities.
[Figure 4.37]
Boujou user interface

[Figure 4.38]
The Foundry’s Nuke 3D tracking interface

[Figure 4.39]
Adobe After Effects’ 3D tracking interface
Mocha

Even Imagineer Systems’ planar tracker Mocha Pro (www.imagineersystems.com) (as seen in Figure 4.40) has been given a turbo boost with its ability to extrapolate 3D camera tracking motion from multiple 2D planar tracks, resulting in some very impressive output where some standard 3D trackers fail.

SynthEyes

One of the first affordable, low-cost, 3D tracking applications, SynthEyes (www.ssontech.com), shown in Figure 4.41, has also grown in capability and features to become a powerful and widely used 3D tracking solution.

[Figure 4.40]  
Imagineer Systems’ Mocha Pro user interface

[Figure 4.41]  
SynthEyes user interface
Concepts of Visual Effects and Compositing

Voodoo
The University of Hannover’s Laboratory for Information Technology developed this free non-commercial 3D camera tracking software. Voodoo (www.viscoda.com) (Figure 4.42) is an excellent tool for beginners to use to experiment with 3D camera tracking at no cost.

3D Matchmoving
Once a solid 3D tracking solution is exported from a 3D tracking application, creating a 3D matchmove involves little more than setting up a scene and importing the solution into your 3D or compositing application of choice, as shown in Figure 4.43 and Figure 4.44. (See Chapter 3 for much more on matchmoving.)

Advanced 3D Tracking Strategies
There are many times when it is extremely helpful to know some advanced 3D tracking strategies as well.

Hand 3D Tracking and Matchimation
Unfortunately, as is usually the case in VFX, 3D tracking is often not quite as simple as autotrack, autosolve, autoorient, and export. Tracks contain too much noise or too many errors or they just downright fail altogether. In these cases, as with 2D tracking and matchmoving, you need a fallback strategy.
Very similar to the hand-tracked 2D track in Chapter 3, when all else fails, you can hand track, or *matchimate*, a 3D track as well. *Matchimation* is derived from the combination of *matchmove* and *animation* and refers to the process of manual frame-by-frame or keyframe matching a track.

To hand track a 3D scene, you first want to create 3D reference stand-in objects for any scene elements with known sizes and/or positions. You are basically trying to replicate key elements of the scene in your 3D application. Elements nearest to the 3D CG object you intend to place into the scene are the most important to place, if possible. In Figure 4.45 you can see a dolly shot sequence filmed on a bluescreen set, which will become an air traffic control radar monitoring station in this example.
Load the footage into the background of your 3D application, making sure the footage size and aspect ratio is set correctly in both the background and the scenes camera. Set your 3D models to wireframe view mode so that you can easily see through them to the footage behind as well as the wireframe edges outlining your elements.

Since I know that we cut the tabletop portions of the “radar stations” to 30 inches wide and left them at their full 8 foot, plywood length, there is a base measurement to start with to build a reference object in your 3D application. In Figure 4.46 you can see two of these, laid end to end, to represent the two workstation countertops. Let’s eyeball the height of these countertops and place them at about 27 inches (the height of my workstation desk, which seems about right). Next, using the camera VFX cues you can ascertain (discussed in Chapter 1), set your camera to a fairly wide focal length and place the camera’s starting position at about 30 inches off the ground and approximately 10–12 feet away from the subject, as shown in Figure 4.46.

Align the wireframe with the counter at whatever point in the shot you choose. Remember, it’s perfectly acceptable to work from beginning to end, end to beginning, middle forward and back, and so on. Keep in mind the information you can deduce from the scene—such as that the camera appears to be on a dolly so will likely translate in a straight line, even if it pans about on its Y axis. Move the camera in a straight line on its local axis until the end (or furthest point) of the shot and pan the camera until the counters and the wireframes align, as shown in Figure 4.47. Set your camera’s first keyframe here.

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Align the wireframe with the counter at whatever point in the shot you choose. Remember, it’s perfectly acceptable to work from beginning to end, end to beginning, middle forward and back, and so on. Keep in mind the information you can deduce from the scene—such as that the camera appears to be on a dolly so will likely translate in a straight line, even if it pans about on its Y axis. Move the camera in a straight line on its local axis until the end (or furthest point) of the shot and pan the camera until the counters and the wireframes align, as shown in Figure 4.47. Set your camera’s first keyframe here.
From here, it’s the same procedure you followed for the hand 2D track, only in 3D. You will move your camera along the guesstimated path to the point where the 3D scene element you’re tracking diverges the farthest from the wireframe before either beginning to return or changing directions. This will be your next keyframe position, and you will realign your camera until the stand-in and on-screen element are aligned, then set your next keyframe, and so on (Figure 4.48).

Then simply repeat this process until the wireframe and scene elements are locked throughout the duration of the shot.

Once this is completed, any object added to the scene—once composited and properly integrated, color corrected (covered in Chapter 5), and rendered—should composite and integrate nicely, follow the motion of the scene, and appear to actually exist within the scene, as shown in Figure 4.49.

[Figure 4.48] Camera aligned with scene element to next keyframe position

[Figure 4.49] Integrated 3D air traffic radar workstation set piece
3D Object Tracking

If we defined 2D stabilization as simply 2D motion tracking data of a piece of footage, inverted and applied back to that footage, you can think of the inversion of 3D camera motion track data as object tracking. Where the output of a 3D camera track is a static scene and a moving camera, the output of an object track is a static camera and a moving object or scene. This technique is particularly useful in cases such as adding 3D prosthetics or props to moving characters, covered in detail in Chapter 7.

Motion Control and Motion Capture

Finally, no discussion of matching camera movements would be complete without discussing motion control and motion capture.

Motion control is the utilization of computer-controlled robotics (Figure 4.50) to very precisely create, record, and repeatedly play back camera movements over and over again. This allows for the combination of complex slow motion, or replication shots, such as adding clones of the same character to the same scene all within a continuous moving camera shot. On the pro side of this technique, motion control shots are very precise, align perfectly, and allow amazing seamless integrations. On the con side, motion control robots are expensive, huge, slow, and unwieldy and take a lot of time to set up, rehearse, and tear down.

[Figure 4.50]
3D illustration of a motion control camera rig
Similarly, motion capture, though not actually camera tracking either, is the capture of object motion data (as you would get with an object track) via various forms of data capture ranging from optical to wireless sensor arrays, as shown in Figure 4.51.

Motion capture is mainly used for the recording of lifelike organic character motions and interactions, and although used extensively in VFX for 3D CGI character and digital doubles, it is more in the realm of 3D character animation than VFX and compositing.

Now that you understand the basics of VFX, 2D, and 3D, let’s jump right in and begin integrating some CG VFX in Chapter 5.
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