texturing for dummies

Need a little help learning the basics of creating textures? Look no further, as this guide will teach you the basics you need to know to get started, from basic definitions, to texturing theory to basic UV mapping fundamentals and more.

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Introduction

Welcome to this, the newly updated 2006 version of this article. I realised that the original 2002 version of this article had become horribly outdated, and in some cases the information was simply incorrect, so I have spent some time re-writing it, and enriching it with additional information.

The point of this article is not to provide any pointless step-by-step instructions on creating textures, because in the end those don't really teach very much at all, and instead of actually teaching concepts, all they tend to do is demonstrate a single approach to a specific situation, leaving the artist with little knowledge about how to tackle a variety of texturing issues that he or she is bound to face on a regular basis. Instead, this article simply discusses the *theory* behind texture painting, thus enabling you, the artist, to understand *why* and *how* this process works, so that you'll be properly equipped to handle texturing tasks in the future.

A short note on terminology

It is worth spending a moment here at the beginning to discuss the difference between a texture and a shader. This article is not about shaders as such, but rather about the various mappable components of a shader, such as diffuse, specular, bump, etc. Roughly speaking, a shader defines the way in which light interacts with the surface, thus determining the actual quality and substance of it, whereas textures simply add details that the shader alone cannot. Understanding how the different properties of a shader works enables you to successfully create textures for each of these components, in order to create realistic and effective materials for your objects.

Look at the world a little differently

As a texture painter, it is vital to be able to observe the world around you in such a way as to enable you to understand exactly what you need to create within the computer generated environment in which you work. Merely observing the world on a superficial level is not sufficient.

Take a look around you. What do you see?
Naturally you see the world that you have been looking at every single day of your life.

Now take another look around you. This time, concentrate on every different surface that you see, and describe to yourself exactly what the surface looks like. When you begin to describe what you see, you will notice that every surface is comprised of many different qualities.

Concentrate on one particular surface near you. What colours are in the surface? Look for uneven tones or grit that may create variations. Are there any scratches, fingerprints, or other blemishes or imperfections in it? Is it reflective? Does any light penetrate the surface? Questions such as these will help you to understand exactly what you need to create in order to recreate a surface such as the one that you are looking at.

Touch the surface. Is it hot or is it cold? Smooth or rough? The actual tactile quality of the surface is very important. To make a texture believable, you have to be able to convey to the viewer exactly what the surface would feel like if they were to reach out and touch it. The art of creating textures is so much more than just defining the colours of surfaces; it is about creating the quality and tangibility of them too.

To become a texturing artist, one needs to observe and experience the world in this manner. Make a habit of noticing all the tiny details in everything, and how they alter the way in which you perceive the actual surfaces.

These are the details that you have to create in order to make interesting and believable textures. Developing a keen, perhaps almost rabid, fascination with such detail is the key to becoming a great texturing artist, as it equips you with an excellent understanding of how things look in the real world.

I cannot emphasize enough the importance of this kind of attitude. You have to become excited about the way things look. That way, you will find the process of recreating them exciting and enjoyable too.

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Time and Weather

It is safe to say that nothing in this world remains untouched by time or weather. One of the biggest mistakes made by texturing artists is overlooking, and consequently excluding, the effects that the world, as well as just the mere existence of the object in question within the dimension of time, has on any surface.

When texturing things that generally remain on the outside in the world, as opposed to things that are usually sheltered, you have to consider how the weather will have affected it over time.
The sun, rain and wind affect everything outside in this world to some degree.

Whether these things are manmade or natural, the weather takes its toll on them eventually.
The two most damaging aspects of the weather are the sun and the wind. Rain does have a considerable impact on things, but since there are no places on Earth where it rains every single day, its effect is not as consistently damaging as the other two, but rather plays a slightly different role, discussed in a moment.

The sun dries things out, causing colours to fade, and substances like paint or mud to become brittle and crack, while the wind blows minute particles of sand and other debris around, gradually causing minute erosion on everything.

The wind can also create very tiny subtle details, such as grains of sand in paint and varnish, which may have become stuck in the coating while it was drying. The wind also, obviously, carries dust and other dirt around, causing it to become lodged in cracks, scratches, joins and any other abrasions or irregularities on surfaces.

The effects of rain can have quite an impact on the appearance of things. Apart from the obvious examples such as streaking paint and dirt, it also causes streaks of rust to form over time. Areas that experience a fair amount of rain will generally produce foliage that is far more lush and green than areas that do not. It is essentially, and in most cases, not so much a damaging effect, but a nourishing one.

Of course it can also be a destructive force, as in the examples of cyclones and other tropical storms, but since water is, for the most part, one of the main sources of life on this planet, its effect is usually a more appealing and welcome one. Areas that have a lot of moisture present, and especially if they also have less intrusion from the sun, tend to develop features like moss and lichens, which convey to the viewer what the environment feels like.

Notice the manner in which all these weather elements affect different substances in different ways. Bricks weather in a different fashion to wood. Depending on their construction or the substance from which they are made, some surfaces are able to withstand these effects better than others. Treat each individual surface in the unique manner that suits it.

The effect of time is easy to observe. The longer something exists in this world, the more wear and tear it will have. An old building is not going to look as clean and perfect as a newly built one. Even if a really old building is still in good condition, structurally speaking, its walls and windows are going to show ageing in some form.

The Human Touch

Humans have a remarkable effect on their surroundings. Every single day of our lives, we go about from place to place, leaving our mark on everything that we touch. And this goes beyond just mere fingerprints and footprints. The way in which we handle items that we use determines, to a large degree, the manner in which they gather dust and grime, as well as develop telltale signs of wear and tear.

(photograph)

Consider this everyday example: your computer keyboard. No matter how much you clean it, you will never completely remove the marks that you leave on the buttons. As I mentioned before, these marks do not have to be literal streaks of grime. No matter how faint the marks are they are there to stay. Eventually, the buttons are going to develop a slightly different quality on the very spot, on each key, that your fingers generally touch. When texturing anything, you have to consider what manner of human interaction affects the object. Consider not only the actual manner of interaction, but also the frequency and purpose of such use.

CREATING A TEXTURE FOR SOMETHING IS MORE THAN JUST DEFINING ITS COLOUR AND TEXTURE. IT'S ABOUT CREATING A SENSE OF IDENTITY AND HISTORY FOR IT.

Telling a Story

Now that we have discussed the effects of time, weather, and human interaction on the surfaces of all items that we find in the world around us, we can begin to put all of these together and start adding further unique details to each texture to create, for the viewers, a sense of history for the surface that you are making.

This makes the textures not only far more interesting to look at, but also a lot more believable. The key to believability lies in convincing the viewer that the object has some sort of purpose, and conveying the manner of that purpose by creating subtle details on its surface that give an indication as to what function the item may have in this world.

Creating a texture for something is so much more than just defining the object or characters colours, light reflection and absorbance properties and so on and so forth. It is about creating a sense of identity for it, and for giving the viewers an idea of where this item or character has been and what it has been doing.

For example, if you were to create textures for an old book with a soft cover that has been read many times, what sort of details could you add to it that could make it look unique? What details could you include that might give you some indication of who has been reading the book?

Perhaps you could add an old ring-shaped stain from the bottom of a coffee mug onto the cover, where some person placed their cup of coffee one day. Or maybe one of the corners of the book has become dog-eared and bent, as happens with many soft cover books. These details could tell the viewer that perhaps the reader of the book is not very careful when reading, or does not particularly care about keeping the books he owns in good condition.

You could even add a detail such as a persons name or a small doodle having been pressed into the soft, lacquer coated cover, done by a person who may have been bored. Or perhaps, at one point, somebody accidentally tore the cover very slightly, and then mended it using a piece of tape.

Very well read books also tend to develop wrinkles in their spines. If you wanted to indicate the book has been read many times, you would not only make the cover a bit grubby, but you should also add things like wrinkles along the spine, or slightly dog-eared pages.

Details like this are not merely examples of basic human interaction, because they are not universally common to all objects of the same type. Not all books are going to look very similar after a few years of use, as some books may have been in the possession of people who looked after them very carefully, whereas other books may have been abused somewhat.

For example, if you were to create a book that belonged to a small child, you could add details such as old food spills, or even crayon pictures scrawled on the pages, that would result from being in the possession of a clumsy, or creative child. Looking at details such as these, especially a detail such as childish scribbles, the viewer would immediately be able to conclude that the book had, in fact, belonged to a child.

Let us explore another example of this. Let us imagine that you were to create textures for a car. How could you add details to the texture that would give the viewer an idea of the history of the vehicle?

Firstly, you should indicate what sort of person owns the car. To give a clue as to the nature of the vehicles owner, we should decide on an appropriate colour for the car. A bright red car with yellow speed stripes may indicate that the owner is young and bold and outgoing, whereas a plain white or black car may belong to a more sophisticated, and possibly more conservative owner.

The condition that the car is in can give us further clues as to the nature of the owner. If a reckless teenager, or even an old person with somewhat impaired senses, owns the car, then it is more than likely that the car will have bumps and scratches on its front and back fenders from clumsy parking, or scratches on its body from scraping against walls or barriers.

Decorations can say a lot too. A teenager might also have lots of stickers all over the bumpers and rear window, whereas an older, more responsible person might just have an AA decal on the front window.

Perhaps the person who owns the car likes to travel a lot in the vehicle, in which case he may have collected many decals from his various destinations, which he has stuck on his rear window. People who travel across country borders in their vehicles often display a decal with their own countries flag on it.

Secondly, what sort of environment is it in on a daily basis? And where has the car been? If the car is kept outside, then it will have become more damaged from the weather than one that is kept inside a garage.

Thirdly, what is the car used for? A 4x4 pickup truck is likely to be used for safari trips and off-road adventures, which means that the actual body of the car will probably show signs of such activity. Details could include mud that has sprayed up from the road and dried along the base of the cars body.
At the other end of the scale, a car that is only used for shopping trips and picking the kids up from school is likely to be clean and in good order.

All these examples that we have explored illustrate the details that we need to include in our textures to create a sense of identity, purpose and history for the objects that they are to be used for. Remember, in order to enthrall your audience and capture their attention, you need to give them something that they can identify with, and therefore believe. So when you are creating textures, always begin by building up some kind of visual story to communicate to your audience some of the details of the life thus far of your objects and characters.

Gathering references

An absolutely essential tool for any texturing artist is an excellent library of references. Whenever you come across a great picture of any kind of substance or surface, scan in into your computer, or save it from wherever you found it, and stash it away for future reference. This will help you enormously, as you should never work without some kind of idea of what you are going to create.
Although a lot of details such as we have discussed here can be created straight from your imagination, the actual qualities of a surface, in terms of its physical properties, are usually best created using a number of good reference images to ensure that you establish all your main settings quickly and efficiently.
It is also a good idea to have an extensive library of images for when you are trying to give your client an idea of what kind of look you will be creating for a certain object. This saves a lot of time, especially since it is always annoying when you work for a few days on something only to find that the client had envisioned a slightly different look for it.

Surface Properties

In order to properly create textures, you must understand how the different properties of a shader work, and how textural tones affect them.

Different shading models (eg. Blinn, Phong, Lambert, SSS, etc) can have different mappable properties, and to list and explain each and every one of them would take an entire book on its own, so we'll just cover the most common properties here.

Colour / Diffuse

Most commonly labeled as "diffuse", this is the component of a shader that determines the overall colour of the surface (although sometimes you'll find colour and diffuse seperated, in which case the diffuse parameter can be used to darken or lighten the overall surface).
It is important to note that when dealing with non-game texturing, you should avoid painting in shadows or highlights in your textures. Unlike in the case of games, where lighting details are often painted into the textures because of a lack of realtime lighting in the game engine, diffuse textures for other mediums (film, television, etc) should just contain the raw colour.
The following image shows an incorrect image on the left, and the corrected version on the side. Fixing this was a simple case of using the clone tool in Photoshop.

Of course, when dealing with photographic textures, you almost always have to do some shadow/light removal before the images will be suitable as textures.

The reason for removing the light is simply because the lighting is set up in your scene file, and when you have lighting information in your textures, these can clash with the scene lighting.

Another important thing to bear in mind when creating diffuse maps is that no surface in this world is ever really a solid colour. It is important, for realism, to create variations in the colour, even if these variations are very subtle. This world is full of imperfections, so ensure they're there in your textures.

A matter which could cause some confusion is the difference between diffuse and *diffusion*. While diffuse, as explained here, is a surface component that essentially creates the colour of the surface, diffusion describes the scattering of light within a surface. These are two very different properties and should not be confused - diffusion is associated with subsurface scattering shaders.

Lastly, when creating texture maps for your diffuse property, be sure to place colour detailing in areas that have a change in surface quality. For example, if you're creating textures for scratched metal, the scratches should be a slightly different colour to the surrounding metal. This is particularly important once you apply your bump and specular and reflection maps, as it looks strange if you have all these details being created on the surface in your other surface properties, but not in your diffuse map.

Quick Tip
When creating very reflective surfaces, like mirrors or other shiny metals, set your diffuse value very low, even all the way to black. This is because very highly reflective surfaces essentially show very little colour of their own, as we instead perceive the colours of the reflections we see on their surfaces.

Specularity and Reflection

Most things in our world are shiny. Some things are more shiny than others, but there are very few things that we encounter that are very matte. When we see shiny highlights in the real world, what we're actually seeing are reflections of local light sources.

In a CG program, we have two main ways for creating shininess on a surface. The first is specularity, and the second is reflectivity.

In reality, the effect known as specularity in CG is actually called specular reflection. A dictionary definition would describe specular as a "mirror-like quality". However, unlike it's real-life equivalent, the effect of specularity in it's 3D package incarnation, as we are familiar with, is actually simply a way of faking the reflection of light on the objects surface. Let me explain.

If you observe a shiny plastic cup in a room that is lit by a single light bulb, you will notice highlights all along the surface of the cup. Now, if you look really closely at these highlights, you will discover that they are actually reflections of the light bulb itself. Obviously lots of surfaces don't have very tight, defined hotspots which are as clear as they would be on a plastic cup, but all that has happened is that the reflection has become more spread-out, due to tiny irregularities in the surface.

Now that's how it works in the real world... In CG, specularity is fake because it doesn't actually reflect the lightsource in the same way that the surface would in reality, instead it just gives the illusion that the surface is reflecting light. In other words, it shows highlights simply because there is light shining on it. It isn't actually reflecting anything as such.

On the other hand, reflectivity actually tells the renderer to raytrace reflections on the objects surface. This doesn't necessarily mean that everything will look mirror-like though - subtle, blurry reflections look great on all kinds of surfaces, from human skin to dull plastic. Of course, the compromise is that specularity is "cheaper" to render, as it is a fake and requires no reflection calculation.

When creating maps for specularity and reflectivity, you generally use gray values to determine which areas are more specular/reflective than others. With most renderers, lighter gray areas in the texture will increase the effect. Things to consider when creating specular and reflectivity maps:

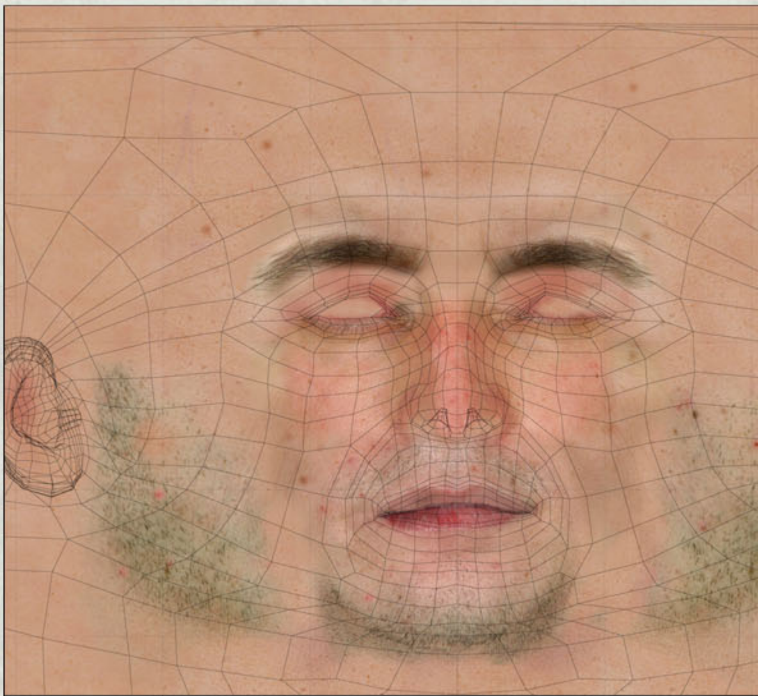
Variation! No surface in reality has a perfect, consistent shininess. Everything has been touched in some way by something – whether by people, animals, the weather, or anything else. These things will leave fingerprints, smudges, scratches and other artifacts that will lessen the shininess of the objects surface. It is important to include details like this, as even if they may be really small and almost indistinguishable, they are nevertheless essential details for realistic real-world surfaces.

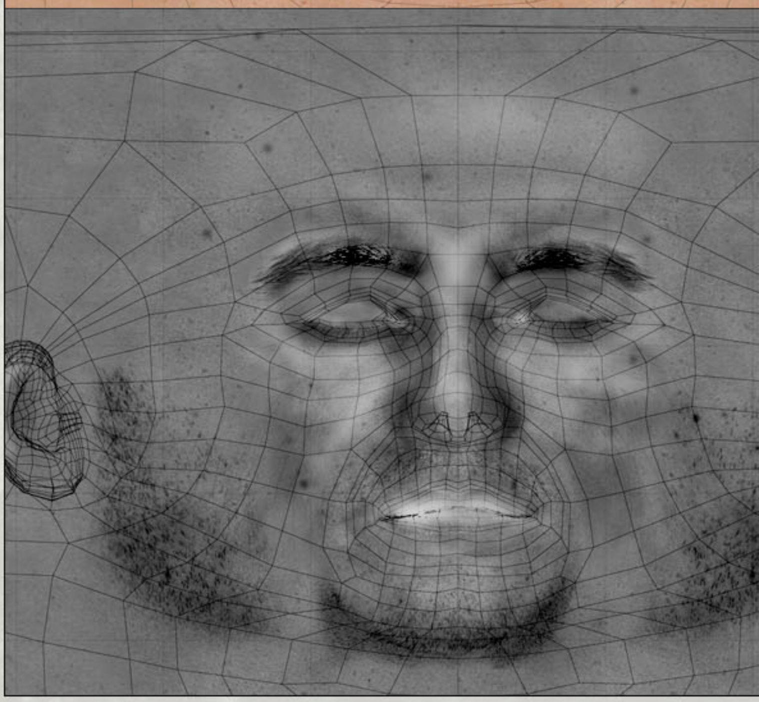
Show some weathering. The weather, as I mentioned above, leaves obvious marking on surfaces. These sorts of marks include drips, stains, drying, damp and that sort of thing on items. Remember that this sort of damage should also be included in your colour and bump maps, and are further enhanced by including them into your specularity/reflection maps as well. For instance, the paint on a house will, over years, begin to show weathering from rain and sun – in terms of damp gathering in corners, streaky drips down walls, and drying out and cracking where it has been faced by too many hours in the sun. Obviously these details will go into the afore-mentioned colour and diffusion maps, but altering the specular/reflection maps will add more detail to these effects – in terms of the dried, flaky paint will have a broader, less strong shine too it than areas which are in constant shadow, and have become damp.

Surfaces that are scratched – remember that with abrasions and scratches, the shininess tends to change. For instance, if you have a piece of metal that is painted, the paint will have certain shininess. But where there are scratches in the paint, the metal beneath will show through, and the metal will have a different shininess to the paint.

Basic human interaction with objects leaves very specific and identifiable marks – particularly from fingerprints. Our fingertips are very oily, and tend to leave visible residue on everything we touch. For example, if you handle a wine glass, you will definitely leave fingerprints on it, that will alter the reflections in the glass.

For human skin - Look carefully at a face. Notice how the shininess of skin is uneven. A classic example of how shininess differs in skin is to look at the area of skin where the nostril meets the cheek on the face. Almost always, the skin in this area is drier and ever-so-slightly rougher, causing it to be a lot duller than the cheek. The tip of the nose is almost always rather shiny too. If you have any scars, you will see that scar tissue is much shinier and more reflective than normal skin too. Also look closely into the wrinkles on the joints on your fingers, and you will see that the skin there is smoother and shinier. If you are texturing skin that has any tattoos on it, you should note that tattooed skin is also much shinier, as it is technically also scar tissue.





The above images show a very basic example of a quick diffuse map and a quick specular map. Notice how the areas around the mouth, nose, corners of the eyes and cheeks are lighter so as to make these areas appear shinier in the render. This is a very rough, five minute effort to simply demonstrate a basic idea for a human face map.
If this image were to be applied to the reflectivity parameter of the shader, it would probably be far too strong, and would need to be darkened a lot before it would be suitable for skin.

Blur your reflections – if your software has the option of blurred reflections, for heavens sake use it!
Unless you are texturing a perfectly clean mirror, most reflective surfaces have a certain degree of blurring to them. Even just slight blurring can help to get rid of that nasty CG look.

Specular blooms – blooming is basically an effect from very, very bright highlights, where the highlight almost seems to glow. This is very noticeable on things that have been covered in some sort of lacquer – such as car paint. The finish on car paint often tends to give off extremely bright highlights when the car is in the sun. Looking at these spots usually gives you mild retina-burn – I'm sure you all know the effect I'm talking about. It's almost like a mini-lens flare, in that it is sparkly, and has lots of little streaks coming out of it. Most software has some kind of bloom effect, in the form of an extra shader, or specular parameter. If you are working with surfaces that are coated in very reflective substances, then adding a bloom can give it a nice touch.

Fresnel reflections – in reality, the angle between you and the surface of the object that you are looking at affects the amount of light that is reflected and refracted that you can see.
This effect is particularly important when dealing with surfaces which are transparent. For example, if you look at a lake from a far-off distance, it will appear almost completely mirror-like, yet, as you get closer, and the angle at which you are seeing the water widens, the water appears less reflective and more transparent. This is called the Fresnel Effect (pronounced "fre-nel" – the "s" is silent), an effect that gets its name from the French physicist Augustin-Jean Fresnel, who first documented it.

Consult your software documentation for information on implementing this effect in your shaders. With Maya or XSI, you can set up gradient ramps to fake this effect pretty well in individual surface parameters.

Anisotropic reflectivity - rough surfaces cause reflections to behave a bit strangely. I am sure you've noticed the way that highlights on stainless steel, for instance, travel in long streaks perpendicular to the grain of the metal. This is because the machining process that the metal underwent has created thousands of tiny grooves in the surface that, essentially, trap light and create these streaky highlights. Most renderers these days have built-in methods for rendering anisotropy, allowing you to define the amount, and direction, of the roughness on the surface.

The images above show effective use of different types of reflectivity (and specularity) to create interesting lighting on the surfaces in the scene. The vault image on the left demonstates some anisotropic shading for the steel, plus the use of regular reflection highlights creates an interesting array of glittering points in the image. The image on the right uses reflectivity on the ground to create a slightly wet look, while the blurred reflections on the wall bring focus to the center of the image. The metal item hanging from the ceiling, and the two faucets use a classic mirror-like reflection, while the counter with the glass drawers also uses anisotropy. Without all the reflections in these images, they would be very dull and uninteresting.

Lastly, an important consideration when creating specular/reflective maps is to avoid overdoing it. Too much specularity can make things look very fake, giving them that very characteristic "CG feel".

Quick Tip
When working with reflections, always make sure that you give your surface something to reflect! A common mistake with beginners is to try setting up a reflective surface in the black void of the scene, leaving them wondering why they can't see anything. Provide other geometry, or some kind of image-based environment, so that the surface actually has something to reflect.

IMPORTANT NOTE: Blurred reflections, specular blooms, Fresnel reflectivity and anisotropic reflections are all actually shader issues, as opposed to texturing issues. But since they all deal directly with specularity and reflection, this information is provided for an expanded understanding of different types of reflectivity.

Translucency and Subsurface Scattering

Translucency, simply put, is the ability for an object to have light travel through it, or into it to a certain degree, resulting in it appearing to be backlit (in the case of a curtain or sheet), or to appear to have some faint luminous quality of its own (as seen particularly in skin).

As we know, when light hits surfaces, it is bounced (reflected) back off the surface. Well, in the case of translucent surfaces, some of that light travels through the surface as well. This phenomenon occurs in most substances in this world, except metals and some woods.

Imagine a theatre stage with its curtains drawn. If you were to place strong lighting from the back of the stage, you would be able to discern shapes behind the curtain without actually being able to see any real details in those shapes. It's almost as if you can see the shadowy outlines of things. That is an example of translucency, as the material that the stage curtains are made of is translucent, allowing you to be able to see shapes through it when properly lit.

Translucency is different to transparency because the surface is not see-through as such, and so you can't actually see things in as much clarity and detail as you would when looking through glass. This is because you are predominantly seeing the shadows of those objects behind the curtains being projected onto them. If the curtains were made out of metal or wood, which are not translucent, we wouldn't be able to see them. Apart from the shadows, you can also sometimes make out the faint colours of things through the curtains, especially if those objects are fairly close behind the curtain.

Another great example of translucency is when you shine a very strong light under your hand when it is dark, and you can make out faint details beneath the skin. This is because your skin is quite translucent.

Notice how the veins appear darker in the photo, because they interrupt the travel of light through the surface. If the light were stronger, you would also be able to see the outlines of the bones, because the bones would also interrupt the light. Of course, actually modeling bones inside the model isn't always feasible, which is why creating a translucency map is a nice, quick solution.

Okay, so let's imagine that you have to make a texture for a dinosaur-like creatures wing. You could paint some really cool colour maps and whatnot for it and get it looking okay, but think about it – the membranes of the wings would be pretty translucent, wouldn't they? Well, the arm bits of the wings would be translucent too, but lets not worry too much about those in this case. So, to make all the little veins in the translucency map so that they will show up when the light is hitting the wing from behind, we would do something like the example above.

As you can see, it's actually pretty simple. Make lighter shades of gray where you want the light to shine through nicely, and "block" the translucency by adding any darker areas, such as the veins.

Where we have any degree of translucency, we find the phenomenon known as *sub surface scattering*, more commonly referred to as SSS. This phenomenon really would need an entire article on its own to explain, but very simply put, SSS is when light rays penetrate a surface at a particular angle, and then kinda bounce around a bit inside the surface and then leave it at a different angle to that which it entered at, which causes the surface to appear as if it has some illumination of its own.

These days, most renderers have support for this effect, with built-in shaders for calculating it (although many popular SSS shaders actually cheat the effect, as a proper physical calcuation of it is very slow). Mental Ray, one of the most popular renders these days, has a number of options for SSS shaders, and there is a quite a bit of documentation on the web explaining how to set these up and use them.

Unfortunately, SSS has also become a very widely overused and misunderstood effect. Many people think it's this magic tool that is suddenly going to make all their characters look totally real, so they go and pump way too much of the effect into their shaders, and end up with characters looking like large hollow plastic models. It really is important to sit down and read the documentation available on using the shaders properly, because making everything glowy and hollow-looking isn't very cool, and it's not going to magically make your work look awesome if your work isn't very good in the first place.

Transparency and Refraction

Right, we all know what transparency is; so no in depth explanations are really required here. Transparency is the quality whereby a surface is "see through". Glass, Perspex, water (actually most liquids really), some plastics, etc are all examples of transparency in the real world.

Rule number one of transparency: if your surface isn't looking correct, DON'T go and make it blue. This is something that we see all the time with beginners. When people who are new to 3D want to make glass objects, for some bizarre reason you often see them giving the surface a certain degree of transparency, and then... making it blue. Why this is, I don't know, but don't do it. It looks crap.

Okay, so sometimes transparent objects do have a colour of their own, but setting up colour for them often requires a bit of effort, depending on what software you are using. Clear glass is usually best created with a very low diffuse value (often black works great).

Now, for starters, let's quickly deal with transparent surfaces such as clear glass that have no colour of their own. To get the best results, take the transparency all the way to somewhere between 95% and 100% (don't worry, your object won't disappear) and make it a bit specular and reflective. Ideally you want to implement the Fresnel Effect into this. Regardless of what software you're using, this should give you a basic transparent surface.

Remember, that in order for a reflective surface to work properly, you have to give it something to reflect. This could be an actual modeled environment around the object, or an image environment such as an HDR image. Pretty much anything that is transparent is also reflective, so setting up your reflection correctly is pretty important.

Of course, glass isn't always squeaky clean. The photo on the lower left, and the image alongside it, show a dirty glass window, and a rough transparency texture, respectively. In the texture you'll see that the transparency (represented by the white values in the texture) is decreased slightly by the streaky dirt buildup on the glass.

A corresponding colour map would also be necessary to create the slight colour that the dirty streaks have, as well as an appropriate reflectivity map, as the dirt wouldn't necessarily be as reflective as the glass..

Refraction is the bending of light that occurs when light rays travel through substances that are very dense. The light bends because the speed that it is traveling at slows down due to the change in density (from the air), and creates the illusion that objects seen through or inside the substance are displaced.

Take a look at the photograph on the lower right. Notice the way that the spoon appears distorted through the surface of the water? This is because of refraction. The light rays have bent through the water, creating the illusion that the spoon is split in two. Take a look through the water to the bottom of the wall, and see how the line running along the edge of the floor also appears distorted. As you can see, it is not only things that come into contact with a refractive surface that appear distorted; anything that you can see through the surface is shifted slightly as well. You can see how the glass itself has refracted light by seeing how the grout between the tiles, just above where the spoon enters the water, have become somewhat distorted as well.

Different substances refract in different amounts. This is because, in reality, refraction is a result of light passing from one medium to another, which causes it to change direction (bend). The density of the medium through which it is passing determines how much the light rays are bent, and what direction they are bent in. As we saw in the previous photograph, the glass refracted slightly differently to the water, because they are of different densities

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We determine the amount of refraction of a surface in CG by assigning it an appropriate *refraction index*. The refraction index is a number (typically between 0.1 and 2.0, although some surfaces can exceed this) that determines how much refraction occurs in the surface. Lower values produce less distortion while higher values produce more.

If you do a search on the web, you can find lists of refraction index values for thousands of different surfaces, although often you'll end up going with what looks good, as opposed to what's really 100% physically accurate.

Be aware that refraction can add considerable time to your rendering time too, so learn how to optimise your renderer to minimise this.

Incandescence

Incandescence (also sometimes called *luminosity*) makes things appear to be self-illuminated. It really is as simple as that. Nothing more, nothing less. Basically, it makes them luminous, in the sense that they appear to emit a light of their own.

Need to make something look like it has a light of its own? You use incandescence to make things like LED displays, red hot swords, glowing eyeballs, neon signage, flashing lights and fluorescent tubes, to name just a few examples. It is perfect for lighting up those red eyes of your latest hideous demon model, boiling lava in a volcano, doing the energy thrusters and lasers for your space ships, or for adding some electric power to your anime style villain's oversized sword.

The image above shows a simple laptop model with incandescence applied to the monitor and LEDs on the left, while the one on the right has none. The one on the left looks more realistic because computer monitors and LEDs should appear to emit light.

The image below shows a useful method of using an incandescent map (inset) to create the effect of a light coming through a window at night, with the window in this example being a very dirty one. Notice how the dark areas of the map create the effect of blocked light.

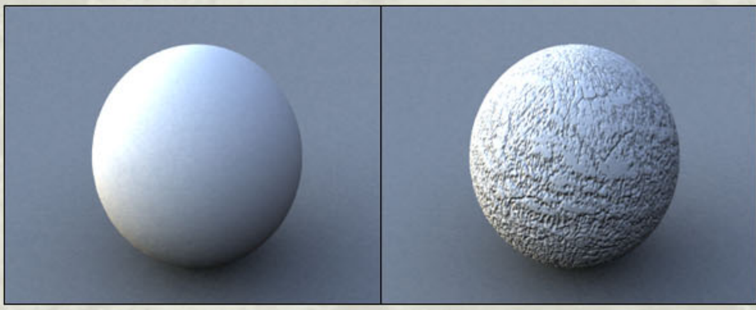
Note: an incandescent value or map in a shader doesn't actually illluminate the surrounding geometry, as it is simply a surface-based effect. However, with many renderers, rendering with photons/global illumination will cause objects around incandescent surfaces to receive illumination from them.

Bump Mapping

Probably the most commonly used surface property along with color, bump mapping is a method whereby you can create the illusion of irregularities or topical abrasions or damage, such as scratches, dents, veins, or any kind of textural grain, to a surface, without adding to, or altering, the geometry of the model in any way.

Because no surface in this world is perfectly smooth, no matter how smooth it may appear, all surfaces you create will require some kind of bump mapping in order to create a sense of actual tangible texture or roughness to the object. Clever use of bump mapping conveys to the viewer an idea of what the surface would feel like to the touch.

It is important to note, however, that bump mapping does not affect the actual geometry of the object, to which it is applied, in any way. It is solely an illusion. This illusion is usually betrayed by the edges of an object when rendered, which will appear smooth, even if a very rough bump map is applied to it. This is demonstrated in the image below.



Even though the bump map above creates noticeable indentations along the surface, the edges of the sphere betray the fact that the surface is in fact completely flat, when rendered. Because of this, bump mapping should be used with a lot of care, and only really for minor topographical details, and never be used to compensate for a lack of geometry that should actually be there.

Bump mapping is great for telling people what a surface *feels like* when touched. Even surfaces that appear very smooth, such as plastic, still have a certain degree of roughness on them, if you look very closely. Adding this roughness to your surfaces greatly enhances their realism, by giving the surface a tangible tactile quality, and by breaking up the light upon the surface itself.

If you were creating surfaces for skin, you can use bump mapping to create the cellular texture that skin has, as well as wrinkles, pimples, moles, stubbly hair, and other irregularities like scars, on the skin.

If you are working on surfaces such as rock and stone, you use bump mapping to create the roughness that these substance have, as well as small holes or tiny cracks that may appear on the surface.

For metals, bump mapping can be used to show grooves from machining, irregularities from rusting, and any other scratches and abrasions.

Displacement Mapping

Okay, so we have discussed the fact that bump mapping should never be used to compensate for a lack of geometry. Well, have you ever wished that there was a way to create geometry using a bump map? There is a way to do that, and that method is called displacement.

Displacement basically takes a texture, and actually deforms the geometry of an object according to the texture used.

Something that you need to consider is when to use just bump map texturing, and when to use displacement. The tricky thing with displacement is that in order to get really great displacing, you need to have extremely high polygon counts on your models, and this can greatly increase rendering time.

However, displacement mapping has increased in popularity a lot in the last few years, along with the release of software packages like Pixologic's ZBrush, which makes displacement map creation very intuitive.

Of course, having the actual details in the geometry itself does look fantastic, but for things like the coarseness of sand, or the grain of skin, using displacements is slightly over the top. In cases such as that, you can get away with using only bump mapping. However, sometimes using displacement for details such as wrinkles in skin, which you can do with just bump mapping, can actually look a lot better when done with displacement, especially since this would mean that these details would be visible along the edges of your model when viewed from angles that would ordinarily reveal the fact that these details were nothing more than an illusion if they were done with a bump map. The image below shows a ZBrush model with displacement.

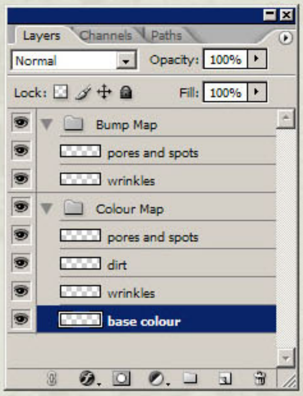
At the end of the day, if you have time to burn on longer renders, and know how to optimise your renderer to get the most efficient displacement results, then by all means, go ahead and use displacement mapping.

IT IS SAFE TO ASSUME THAT ANY DETAIL YOU ADD TO ONE OF YOUR SURFACE ATTRIBUTES IS GOING TO AFFECT SOME OF THE OTHERS, IF NOT ALL OF THEM, IN SOME WAY.

Ensuring Consistency Between Surface Attributes

Now that we've discussed the most commonly used surface parameters, it's worth taking a moment to quickly discuss the matter of consistency between these different textured attributes.

For example, if you're creating textures for rusty, scratchy metal, you must be sure to include the scratches, rust and other details in the colour map, as well as the bump, and specular/reflective maps too. This is because a scratch or a rust patch affect more than just the colour of a surface.



A quick way of ensuring easy copying of details from one surface attribute another is by using Layer Groups in Photoshop (if indeed you do use Photoshop for your textures). This is demonstrated in the image above - see how the different layers for the different details can be easily copied from one attributes folder to another. This saves a lot of time, although of course in order for this workflow to work for you, you have to create your different details on individual layers.

The image on the left shows this example in action.

The top swatch shows the colour map, the middle shows the bump map, and the lower one shows the reflection map. Each one does its part to create the correct effect.

Notice how the reflectivity is decreased in the rusty area, since rust isn't reflective, whereas the actual paint layer is somewhat reflective.

Notice also how even the small scratches are also included in all three maps. In this case, the light scratches are scratching away the blue paint, revealing a lighter coloured layer beneath.

Basically, it is safe to assume that any detail you add to any of your surface attributes is going to affect a few, if not all, of the others too.

UV Mapping

The subject of UV mapping really warrants an entire article of its own (something I intend to write when I have the time), but no texturing intro for beginners would be complete without at least a little on the subject, since it's a vital part of the texturing process.

For many people, the mere mention of UV mapping makes their brains churn and their knees go week. Unfortunately, UV mapping is one of those things that appears intimidating and nonsensical to most newcomers (and even many veterans!) in the CG field, who struggle to grasp the concepts behind this seemingly mysterious, and altogether not-very-widely documented process.

So let me begin by vanquishing a myth about UV mapping: UV mapping is not complex, nor it is difficult. Sure, it can be a right royal pain in the butt, but that's only because it usually means sitting down and tweaking vertices for quite a while. But honestly, that's all there really is to it... a bit of annoying and somewhat tedious vert-pushing and pulling. It can be rather dull but spending time doing it properly means you'll have fewer headaches with textures becoming stretched or squashed on your lovingly-crafted models.

So just what on earth is UV mapping then?

U and V are just co-ordinate axes. You know how when you're modelling, you're modelling on the X, Y and Z axes? Well U and V are just two more axes - the horizontal axis of the 2D map is the U axis, and the vertical one is the V axis.

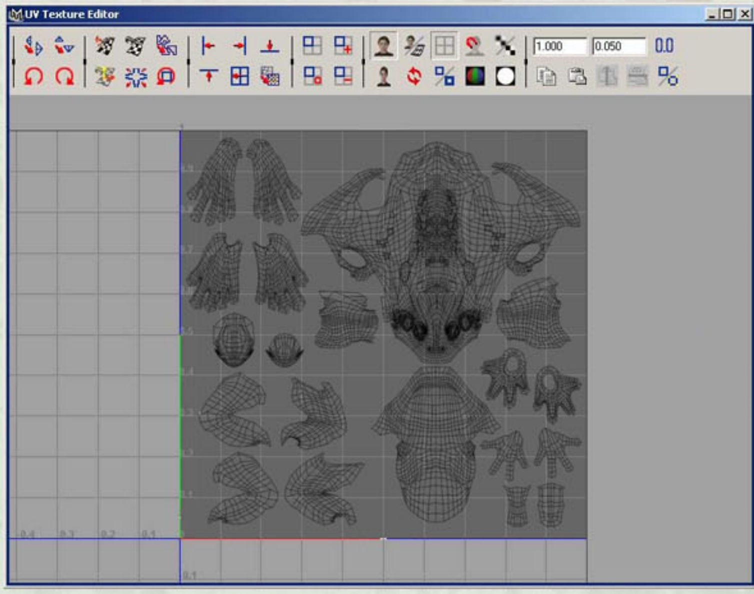
Essentially a UV map contains samples of your vertices from your 3D surface that have been translated into a 2-dimensional plane. Make sense? Each vertex on your model is represented by a vertex in the UV map, as if you peeled off the outer skin of your model and laid it out flat, while retaining the mesh's polygonal structure.

And just as if you peeled an outer surface off an object in real life, this polygonal layout can be independently manipulated by your transform tools (Move, Scale, Rotate) without actually affecting the topology or nature of the geometry itself, but rather affecting only the way in which the texture is applied to the actual map. Most packages have a set of tools, in addition to your transform tools, specifically for the manipulation of UV maps.

So how do we get UV maps? Well, all decent 3D modelling packages will have an *unwrapping* tool of sorts. Unwrapping the model basically gives you the flattened 2D template, which is your UV map. In the UV map, the vertices act like pins, which pin the texture to the model at those points, while the remaining texture is interpolated in between them. Because of this, it is important that the polygons represented in your UV map closely match the proportions of the geometry itself, or else the texture will appear squashed or stretched in areas.

The nifty thing about UV mapping is that it provides you with a very literal, accurate template on which to paint your textures, particularly useful for uneven, organically structured surfaces that cannot easily be textured using standard planar snapshots from your viewports.

Another useful aspect of UV maps is that you can compile the maps for a bunch of different pieces of your model into a single UV template so that you can texture them all in one go with a single image, if you so wish. This is especially common when working on models for games.



Another useful aspect of UV maps is that you can compile the maps for a bunch of different pieces of your model into a single UV template so that you can texture them all in one go with a single image, if you so wish. This is especially common when working on models for games. Different software packages offer different toolsets for unwrapping and editing UV maps, although some are certainly better than others. The image above shows the UV Texture Editor from Maya.

99% of UV maps require tweaking. Sometimes this editing can actually be a long process, depending on the complexity of the model (especially organic models), but it's not really a difficult task to complete, just a time-consuming one. The reasons for editing UV maps are mainly to eliminate, or reduce, potential texture squashing and stretching by re-arranging the vertices to create a template that closely matches the actual geometry proportionally.

The first important step when creating new UV maps is to choose the most appropriate unwrapping method for the model that you want to texture. Different software packages offer a myriad of different unwrapping projection options but generally you'll find the standard cylindrical, spherical and planar mapping options in all of them, with additional auto-map, atlas-style, contour, cubic, shrink wrap, etc options in some packages.
The trick here is to choose an unwrapping type that roughly corresponds to the basic shape of your model. For example, if you're unwrapping a shape that is roughly cylindrical, then unwrap it cylindrically. Due to the nature of UV maps, it is true that any type of projection can be edited into anything else, but choosing an appropriate projection right from the beginning can save some time in the editing phase.

Of course, this can become a bit bothersome when dealing with a model that contains many different shapes along numerous axes, such as a creatures body. However, all you need to do here is approach it in logical sections, by examining the various individual shapes and unwrapping each accordingly.

Packages like XSI have special sub-projection tools especially for such tasks - for selecting pieces of an initial map and re-mapping them along a different axis, using a different projection method, while keeping the selection within the same UV map. You can do this in Maya by simply selecting polygons in the viewport and reappling a texture projection.

Another aspect of planning your projections is the question of where to place the inevitable seams. Because, of course, when you unwrap something, you're going to have seams along the edges. This is a unavoidable fact of life, so get used to it. Thankfully today we have a bunch of fantastic 3D painting tools (Bodypaint 3D and ZBrush are both great for 3D texture painting) available to us, which reduces the seam issue pretty much entirely. If, however, you do not have tools like this at your disposal, you may find this an annoying issue to deal with (which is why I highly recommend investing in a 3D painting app).

Initially, to reduce this problem somewhat, it is advisable to place your seams in hidden areas, or areas seem seldom.

On a character, for example, you could place seams down the back of the legs, the back of the arms, head, spine, etc. This way you can sometimes get away with having slightly imperfectly matching seams once you create the textures.

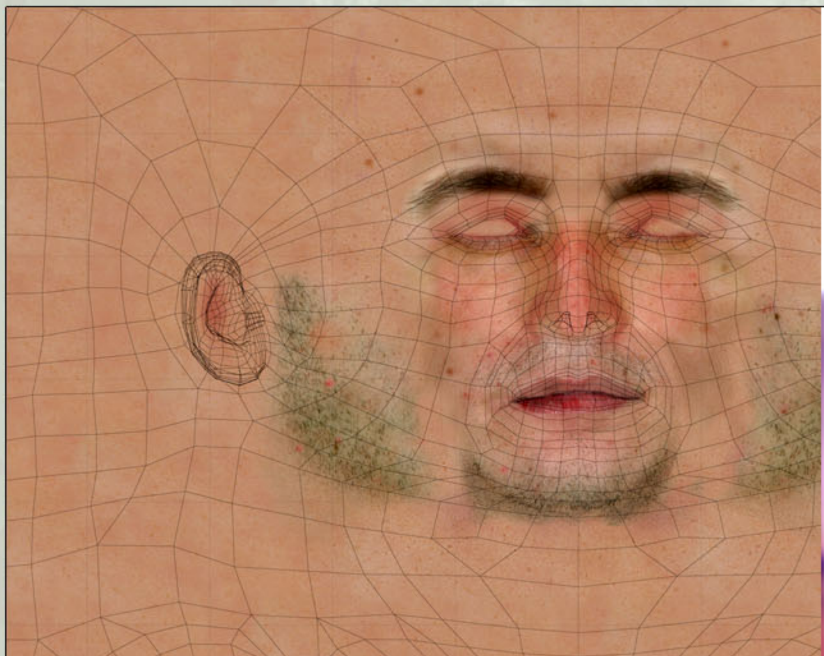
You can also try exploiting structural details on the model for the placement of seams - for example, if you are texturing a clothed character, you could place the UV seams along areas where the clothing is actually seamed. It's not a perfect solution, but it helps.

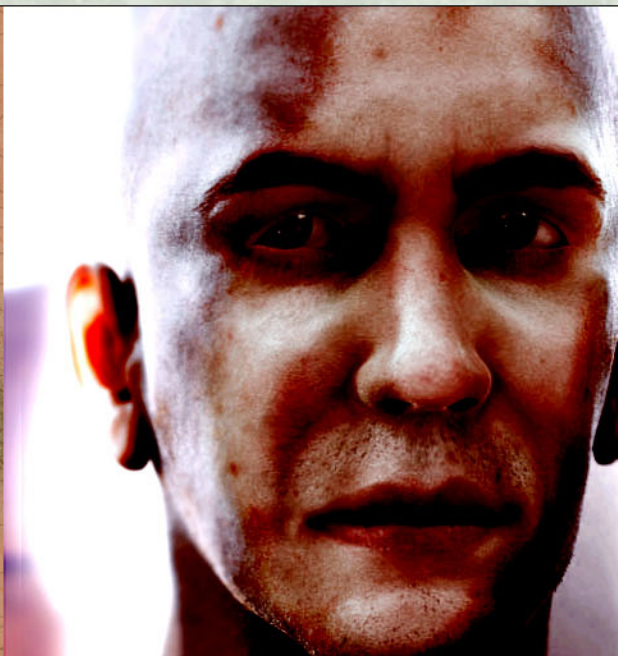
Eliminating the squashing and stretching in UV maps is simply a case of pushing and pulling the vertices in the UV map (usually refered to simply as UVs). During this process, it helps to apply a checkerboard texture to the model, and watch it in the perspective viewport as you adjust the UVs in the UV editor. This way, you can see which areas are being affected. The great thing about a checkerboard texture is that you can instantly spot troublesome areas that require attention.

Luckily most packages do offer some nifty tools to make this process a little less bothersome. Maya, for example, has an excellent Relax function, for smoothing out messy areas of your UV map. With Maya, most UV maps can be laid out efficiently with a simple cut, relax, sew workflow. This process can take a little practise, but essentially all you're doing is isolating areas that need adjusting by cutting the polygons to form islands of UVs that can then be relaxed, and then sewn back together. This is how I personally edit all my own UV maps (a task I find myself doing very often in my particular line of work).

Today there are also a few pelt mapping tools available that are gaining popularity. Pelt mapping is different to cylindrical, planar or spherical mapping in that it attempts to create a relatively accurate layout of the model that looks much like a skinned pelt. However, this isn't a perfect solution as the resulting layout isn't necessarily always an intuitive layout, and almost always requires additional editing anyway.

Note: When a program refers to UVW co-ordinates, it is simply referring to the texture co-ordinates that correspond to the XYZ information of the model, respectively. So the U-axis corresponds to the X-axis, the V-axis to the Y-axis and the W-axis to the Z-axis. The UVW co-ordinates are used to position textures onto the model *in 3D space*, as opposed to extracting a flat UV map to use as a template. So you'll use UVW co-ordinates when placing images or procedural textures by entering in values for their Scale, Rotation and Size and positioning them on the model manually.





In closing, let me take a moment to encourage all those who wish to improve and develop their texturing skills to just give it lots of practise, use lots of reference, and don't be afraid to try new and crazy things. If you get stuck, read your software manual (!!!) or ask someone for help, nicely. And one more thing: while I do personally recommend painting your own textures from scratch when you first start learning texturing, there is nothing wrong with using photographic elements (with the lighting removed from them, of course) in your textures. There really is little room for "artistic purity" in this industry so don't think of it as cheating. If I had a nickle for everytime someone posted online, asking if it was "okay" for them to use photographs in their textures, I'd be rolling in a bath of nickles.

I have additional texturing-related articles on my site that complement this article with additional information regarding texture sizing, as well as Photoshop texturing tips and tricks. These articles can be found at www.onona3d.com. I write new articles from time to time, and hope to add an indepth one on UV mapping soon.

Here are some additional links...

Great Texturing Software

Photoshop - www.adobe.com
Bodypaint 3D - www.maxon.net
ZBrush - www.pixologic.com

Texturing Resources

www.cgtextures.com (the images used in the backgrounds of this article come from this fine free site)

www.ransomactive.com

www.realtexture.com

www.thegnomonworkshop.com (they sell a few texturing-related dvds)

CG Learning Resources

The one and only - www.cgsociety.org forums.

Who the hell am I anyway?

In case you're wondering who I am, and what experience I have... I've been working professionally in CG since 1999, and started working as a texturing artist in visual effects in 2001. This article is based largely on what I have learned over these last few years of working on numerous commercials and feature films. I don't, however, claim to know everything (since we never truly stop learning) and I have over-simplified certain concepts in this article to make them more accessible to beginners.

If for some reason you need to contact me, you can email me at leigh@onona3d.com. Please note that due to my schedule, I can take up to several weeks to respond.