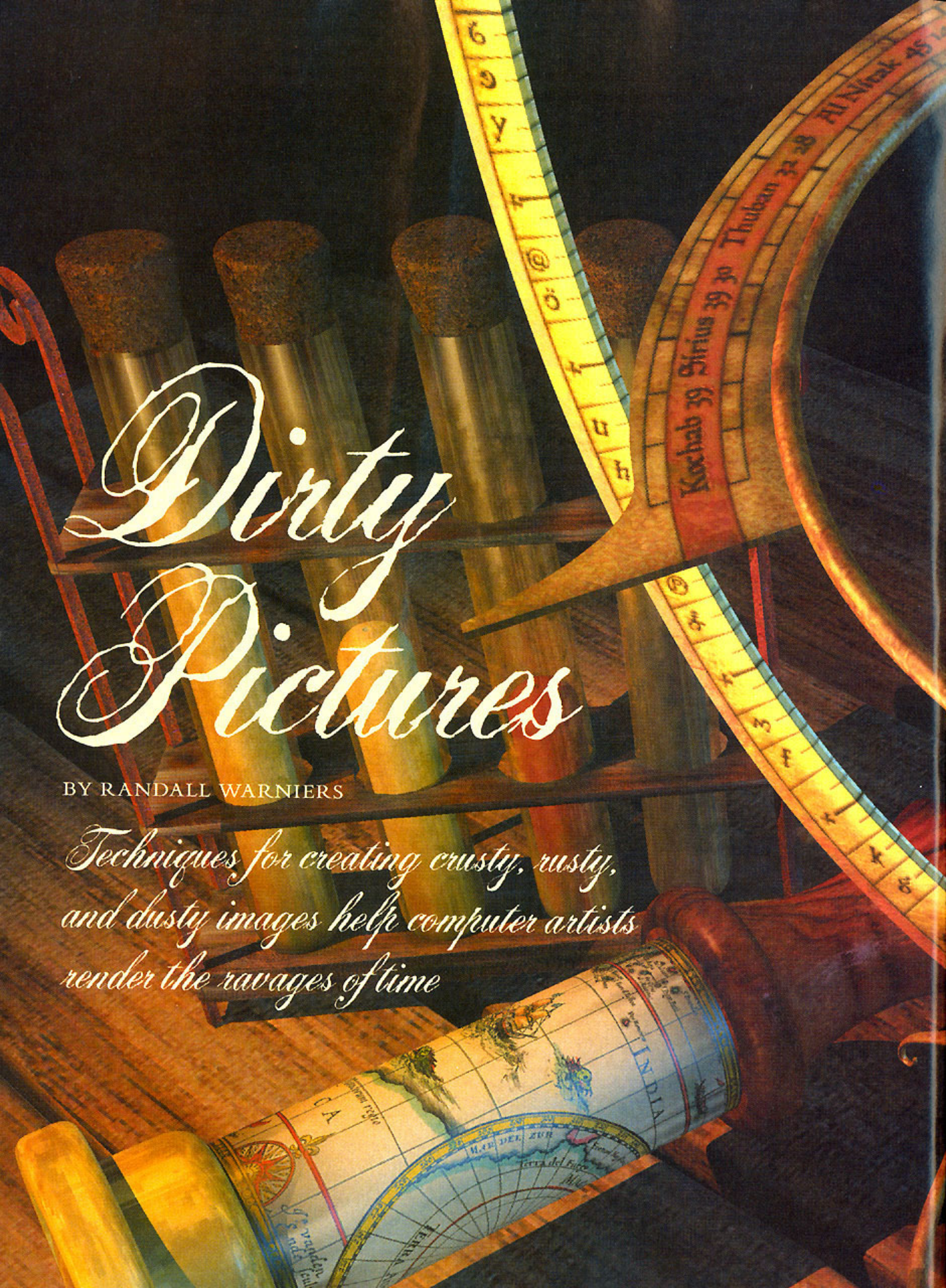


Dirty Pictures

BY RANDALL WARNIERS

Techniques for creating crusty, rusty, and dusty images help computer artists render the ravages of time

In the continuing pursuit of photorealism, computer-graphics researchers and artists have developed elaborate geometric models, complex illumination techniques, and sophisticated processing schemes for rendering lifelike images. A well-recognized problem with many of these images, however, is that they are too perfect and too clean, and therefore unconvincing.

For an image to appear authentic, we need to see the stains—the dirt, decay, and wear and tear—of an inhabited space. The presence of worn and dirty surfaces is an important visual clue that helps us willingly suspend our disbelief and accept the rendered image as real.

We clearly respond to the authenticity of images of a world that looks used. Objects in the various ages of *Myst* and *Riven*, for example, show evidence of dirt, stains, rust, clutter, damage, and wear, which communicates a context of living history and the passage of time, thus adding an important component of realism to our perception of the fantasy.

Joshua Staub, art director and CG production director at Cyan Inc., creators of *Myst* and *Riven*, describes the importance of the used look in *Riven*. "Objects in our 3D environment must appear as though they were really there and, in fact, had been there for a long time," he says. "By adding the agents of age, such as rust, dirt, grime, weeds, and so forth, we're attempting to create a world that not only looks real, but one that looks alive."

The example of *Riven* is a good one: an essential element in the illusion of phtotorealism is imperfection in all its forms, from dirt and clutter to aging and decay. Without imperfections, a

IMAGE COURTESY OF FRANK VITALE

computer-generated image looks artificial and lifeless. When an artist adds elements of imperfection—Staub's "agents of age"—the final visual details of a living, breathing inhabited world are added as well.

Creating Imperfections

Currently the best way to add imperfections to objects in a rendered image is through the use of texture maps. Other methods, including procedural textures, post-render filtering, and direct image manipulation, can also be used, but texture maps are the most widely used method. Texture maps, like holiday paper wrapped around a gift, are two-dimensional images that are applied to a physical model by a renderer. They add enormous visual complexity to simple geometric models, thus allowing scene construction with relatively uncomplicated models. For example, rather than construct a model of a brick wall with intricate physical texturing of bricks and mortar built into the model, an artist could use a bit-mapped texture of a brick wall and render that texture onto a much simpler geometric model. The result—if the texture is a good one—is a surprisingly accurate visual reproduction of a brick wall and significantly faster times for scene construction.

Because dirt and decay can be difficult and time-consuming to draw accurately, the obvious solution for creating a dirty look in an image is to take photographs of dirt and decay and turn those photographs into texture maps. Old, worn, and damaged surfaces of every kind become possible sources of good dirty textures. Asphalt, concrete, brick, stains, scuffed walls, damaged floors, decayed wood, rusted metal, all can be photographed and used as source images for texture maps.

Unfortunately, a photograph of a texture by itself (often called a color map or image map) is not enough to create a realistic-looking image. Even on an intricately modeled object, our sharp eyes perceive the photographed texture as flat and artificial, as if it were painted on the surface. To produce a truly authentic surface texture on a model, an artist needs to enhance the image map

Objects in *Riven*, such as the mag car and the Book Island boiler, look convincingly aged and weathered when rendered with texture maps produced from photos of distressed surfaces.

RIVEN IMAGES COURTESY OF CYAN INC.

by creating some important associated maps—typically a bump map, displacement map, and reflectivity map—to make the texture look authentic. These additional maps enhance the surface appearance of the texture and help make it come alive, as if it has form, shape, and depth in 3D space.

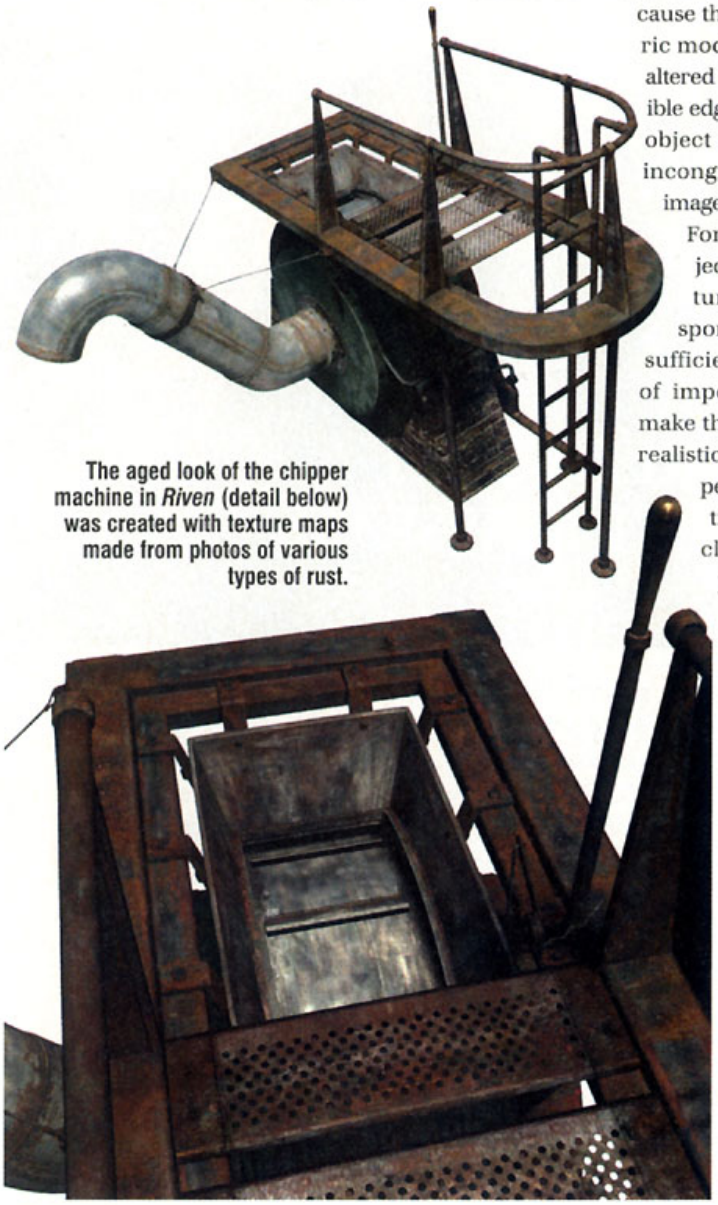
Adding Bumps

The bump map simulates subtle changes in the surface texture, creating slight tonal variations that look like bumps when the surface is rendered. Applying a bump map to an image can be extraordinarily effective in creating a believable appearance of surface variations and imperfections, such as the slight depth differences between brick and mortar in a brick wall and the subtle surface imperfections in the bricks themselves.

The biggest limitation of bump maps, however, is that the illusion of surface variations vanishes on the visible silhouetted edges of the object's surface. Because the underlying geometric model of an object is not altered with a bump map, visible edges of a bump-mapped object appear smooth. This incongruity can destroy the image's authenticity.

For small objects or objects at a distance, a texture map and corresponding bump map are sufficient to add the degree of imperfection needed to make that object look photorealistic, especially when the perceived surface variations of the object are close to the image's pixel resolution. For objects and surfaces prominently displayed in the image, however, a displacement map should be applied. Unlike the bump map, the displacement map actually alters the geometry of a surface, creating physical surface variations that are visible (and self-shadowing) when rendered.

To complete the illusion of a photorealistic surface, artists often include a reflectivity map that indicates which areas in the texture are more reflective than others. Reflectivity plays an important role in the creation of dirty textures because light reflection decreases significantly on those areas of a texture that are covered with dirt, dust, grime, rust, or decay. For example, an artist can make a "clean" texture look dirty by creating a map that covers part of the texture with areas of decreased reflectivity, thus simulating the darker look of dirt.



The aged look of the chipper machine in *Riven* (detail below) was created with texture maps made from photos of various types of rust.

The Trouble with Textures

Texture maps have disadvantages, even though they have been used successfully in thousands of projects. "The quality of the final rendering is limited by the resolution of the original texture map," says Jean-Jacques Tremblay, a Montreal-based digital artist and animator who has worked for Softimage. "Plus, it is hard to get true bump and reflectivity maps. You need a good paint artist to create them."

Texture-map resolution is especially important in animations, where a texture-mapped object that looks authentic at a distance starts to break up into pixels as it moves closer to the camera. To solve this problem, an appropriate resolution must be chosen for all viewing distances. At the same time, extremely high-resolution textures should be avoided to keep rendering times from growing astronomically and to keep texture-image library management under control.

Another shortcoming is that texture maps are more effective with certain objects than with others. Solid objects that don't change shape—walls, surfaces, rocks, roads, machinery, and so on—can be rendered effectively

IMAGES COURTESY OF JULIE DORSEY

Researchers at MIT and Stanford have devised a procedure for creating the look of weathering on metal surfaces, such as the tarnish on this copper Buddha.

with texture maps, while less-solid elements such as water, clouds, gases, and hair cannot be texture mapped well at all.

Texture maps are more successful with static images that do not need to show increments of change. If an artist animates a scene and wants to show the growth of dirt or decay over time, then each scene in the animation requires a separate texture map or at least progressive modifications of a master texture image. These individual modifications can be time-consuming and tedious to produce, which adds to the cost and complexity of an animation project.

Texture Maps for Sale

Two game-development companies are currently selling CD-ROMs of the distressed texture maps they created during production of their games. Omni Creative Group in St. Louis, Missouri, sells a collection of 3D shapes and textures from the CD-ROM adventure *Riddle of the Sphinx*, scheduled for release this month. The collection, called Sphinx 3D Relics, includes libraries of "crusty, rusty, and dusty" wood, metals, paints, paper, plastics, finished stone, rough stone, and "miscellaneous BC and AD" textures. It also includes libraries of dusty and worn 3D shapes, including furniture, lights, torches, coffers, columns, vessels, and various artifacts. The on-line catalog of the Sphinx 3D Relics can be previewed at www.sphinx3d.com.

Another source is Ransom Interactive Textures, which markets stressed texture maps created for the game *The Forgotten*. "The source photography is usually aged and worn," says Kevin Willis, developer of *The Forgotten*. "Reality is the best source for stressed textures. Not much has to be done to enhance it." Most of these textures are stressed urban materials such as concrete, asphalt, brick, wood, stone, and floor coverings, but there are also textures of architectural cut stone, paper, leather, and bark, along with cloud and sky textures and smooth textures of marble. The textures can be previewed at www.forgotten.com/textures.

Yet another source of dirty textures, a CD-ROM called Surface of Reality, is available from Digital Wellsite. According to Alex Lindsay, a digital artist who helped create the surfaces in this collection, these textures add a "subtle level of dirt, dust, and subconscious detail" to an image, helping to enhance the photorealistic authenticity of that image in ways that are often barely perceptible. As an example, Lindsay describes how a certain texture can "create the look of a windshield where the wiper doesn't go." These textures can be previewed at www.wellsite.com.

Other sources of dirty textures are often mixed in with the clean textures offered for sale by vendors. For example, Softimage, in the Altered Perceptions collection of textures, which you can view at www.imag.net/~textures, sells a set of 15 distressed textures in what the company appropriately calls the Dirt Database.

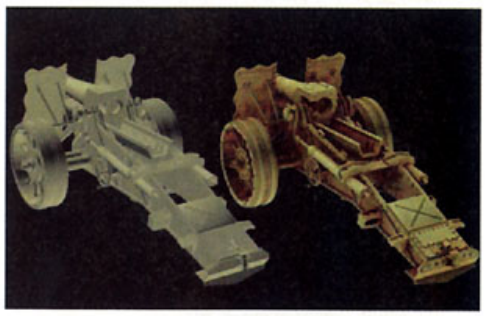
Procedural Textures

Some academic researchers have traveled a different road in their search for dirty textures. Rather than use photographs as the foundation for texture maps, they have developed what are known as procedural textures. These are algorithmic methods or mathematical procedures for generating a specific kind of dirt or decay in an image. The procedures are typically defined in the renderer or in a programmable plug-in or shader that alters a rendered image.

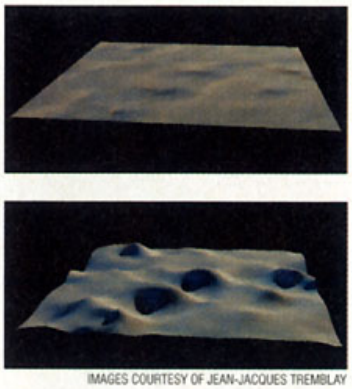
In 1982, Jim Blinn, now a graphics fellow at Microsoft Research, applied the mathematics of light-reflection functions, originally developed to simulate the look of the rings of Saturn, to create the appearance of clouds and dusty surfaces.

In 1990, Welton Becket and Norman Badler of the University of Pennsylvania developed fractal subdivision techniques and applied them to Gaussian and random-distribution models to generate a wide class of surface

DirtyReyes, a plug-in tool for 3D Studio Max, simulates deterioration by applying a procedural aging look to an object such as this cannon.



IMAGES COURTESY OF REM PHOTOGRAFICA



A bump map (top) creates the illusion of surface variations on a smooth object. A displacement map (bottom) alters the surface geometry to produce true imperfections.

IMAGES COURTESY OF JEAN-JACQUES TREMBLAY

imperfections, such as scratches, splotches, smudges, corrosion, mold, stains, and rust.

Gavin Miller in 1994 presented an algorithmic approach for synthesizing the surface appearance of old objects after they have been cleaned or polished to remove dirt or tarnish. His methods, analogous to techniques used in molecular modeling to define surface accessibility in chemical reactions, simulate the look of objects cleaned by cloths that cannot reach into inaccessible areas, such as corners and scratches.

In 1995, Siu-chi Hsu and Tien-tsin Wong, researchers at the Chinese University of Hong Kong, devised a procedural method that automatically determines the amount of dust on surfaces, taking into account the surface texture, inclination, and exposure. The procedure calculates the amount of dust on visible surfaces by combining the effects of gravity, wind direction, surface shape, and the actual source of dust particles. The computed dust-accumulation patterns can be stored as texture maps for future use.

In 1996, Julie Dorsey of MIT and Pat Hanrahan of Stanford developed a procedural approach to modeling tarnish on metal. They represent a metallic surface as a series of layers and then simulate the patina that de-

Transforming Textures

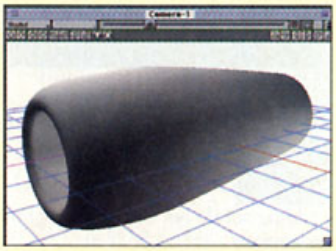
Frank Vitale, a Scottsdale, Arizona-based digital artist who has worked at Presto Studios and Banned From the Ranch, specializes in a technique he uses in conjunction with Photoshop that he calls "dirty it down, scum it up." For Vitale, the realism of a photograph is simply a starting point for adding history (i.e., dirt and scum) to a good texture. He begins by transforming the starting image into a wrapping texture. "The left and right sides of the image need to match seamlessly, as do the top and the bottom," he says. This step is necessary so the image will tile correctly on large models. Then he adds cutlines or seams in the panels where dirt would collect. By using creative combinations of layers and tools such as Gaussian blur, noise, and spatter, along with layer masks and opacity controls, he can adjust the contributions from each of the texture-map layers until the image has the precise degree of aging, dirt, and scum he wants.

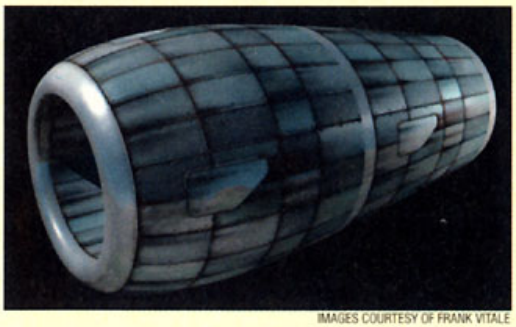
Vitale then makes a channel for the bump map. For this, as with the components of the image map, he often creates on more than one Photoshop layer, building multiple levels of noise and undulation into the bumped surface. He then previews the quality of the fabricated bump maps by using the lighting effects in Photoshop.

The next step is the creation of a channel for the specularity map, which determines how the dirty and distressed texture surface reflects light, particularly bright highlights. He loads the various dirt and scum layers from the image maps into the specularity-map channel, and decreases the degree of specularity of the texture in the dirty areas and at cutlines and seams. This creates the darker look of dirt and scum that accumulates in physical layers over time.

He also adds other details such as nicks and scratches to the texture by using the single-pixel pencil tool to add specularity in the dirt, thus creating the look of scratched or flaked-off dirt, with varying degrees of the original material showing beneath the dirt. This added detail in the specularity map is especially effective in close-up views of the object.

The pursuit of perfection in the creation of dirt, like any creative task, is time-consuming but ultimately rewarding. It is also self-absorbing. "The next time you tear yourself away from your computer," Vitale says, "analyze the surfaces around you, and before you know it, you'll be looking down at the sidewalk and muttering to yourself, 'Hmmm, nice scum map.'"





Texture maps developed and modified in Photoshop can be applied to 3D models such as this jet cowling (top) to simulate the effect of age and wear (below).

IMAGES COURTESY OF FRANK VITALE

IMAGES COURTESY OF JEFF TOBLER, OMNI CREATIVE GROUP

Textures available from the game *Riddle of the Sphinx* include 4000-year-old cedar wood, red paint, and an Egyptian wall painting.

velops on the surface by applying a collection of procedurally defined operators, such as "coat," "erode," and "polish," to the layered structure. This procedural method is significant because it recognizes the underlying physical and chemical properties of different materials and simulates the changes in the appearance of material surfaces as the material ages. The modeled layer structure of the copper object is output as a series of material properties and texture maps, which are then passed to the renderer.

Procedural Tools

Despite such advances, the creation of procedural techniques for showing aging, weathering, or decay in a rendered image have been surprisingly underdeveloped. Currently, the development of procedural texturing techniques has been largely an academic pursuit, with few commercial applications.

However, one commercial tool that can perform procedural dirty rendering is a plug-in for 3D Studio Max called DirtyReyes, from REM Photografica (Madrid, Spain). This tool creates the look of dirty or weathered surfaces by simulating the effects of deterioration, decay, and the wear and tear of everyday life. It works by procedurally calculating the gaps between surfaces, corners, and overlapping edges in an object and then applying the look of dirt or weathering to the material in these gaps.

Other commercial tools include the Natural Shader series for version 5.6 of Newtek's Lightwave 3D (see www.newtek.com). These procedural shaders simulate the look of rust and water stains in an image. Parameters that control the degree of damage can be evaluated and adjusted through a real-time preview interface. These shaders examine the geometry of an object and select regions such as grooves or edges where the effect of rust or staining is most likely to occur. Also available is the MultiPatinae material shader from Phoenix Tools, which can be viewed at www.phoenix-tools.com.

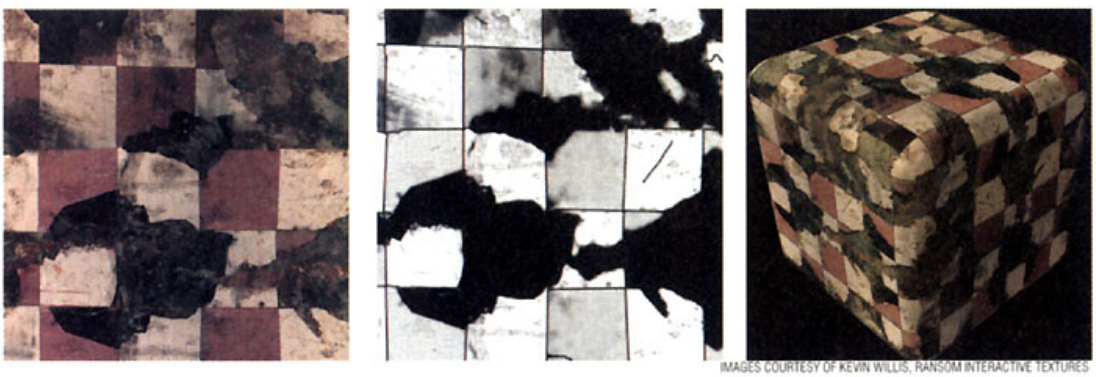
What's Next

For many images, textures are the essential component needed for a convincing photorealistic rendering of an inhabited environment. With sophisticated production tools and libraries of detailed surface textures, a team of artists can produce imagery that describes a world as if that world had been photographed—almost—by a camera. What more can be done? Who can top the dinosaurs *in The Lost World* or the stunning visuals in *Riven*?

One area of unclaimed research territory is the development of textures that authentically reproduce the subtle shadings and color of human skin. Perhaps someday, advances in skin texturing will allow us to see singing cyberteen Kyoko Date slowly age before our eyes, gathering weight and wrinkles with each passing year. It's a texturing effect we'll all come to know, because we'll see it ourselves each day in the most effective real-time phtorealistic renderer of all—the bathroom mirror. CGW

Randall Warniers is managing editor of the Lincoln Laboratory Journal. *He can be reached at warniers@ll.mit.edu.*

A distressed surface, like this image of broken tile (left), translates into a 3D illusion of complexity when it is bump-mapped (middle) and applied to a simple object such as a beveled cube (right).



IMAGES COURTESY OF KEVIN WILLIS, RANSOM INTERACTIVE TEXTURES