TEXTURE IN A LOW COST VISUAL SYSTEM

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ABSTRACT

This paper describes the basic applications of texture in a low cost visual system. Texturing, as applied in this paper, is defined as the modulation of the intensity of a color on a surface. This gives a more natural appearance to the surface at a relatively low cost to the system. The use of texture to produce realistic movement, to create spacial effects, and to give the viewer a realistic feeling of perspective greatly improves the training capabilities of visual simulation systems.

HISTORY

Texturing plane surfaces in a visual system is not an entirely new concept. Blinn and Newell took the idea of mapping an image onto a smooth surface and extended it into mapping synthetically generated texture patterns and highlights onto surfaces.[1]

General Electric used texture patterns to simulate three-dimensional objects in a system called the NASA Surface Generator. The output from this digital ground plane generator was one of the first systems to use the concept of a nested hierarchy of texture patterns.

Later, edge generation was added to the system to allow other surfaces to be modeled. The current low-cost systems have had the ability to generate many surfaces using edge-face definitions, but are turning to texture as a way to increase scene complexity.

INTRODUCTION

The use of texture in a low cost system not only enhances the visual simulation of a scene for a viewer or trainee, but also allows the modeler much greater flexibility in generating data bases. As texture modulates the interior of the surface it is applied to, the modeler no longer has to use many surfaces to delineate specific features.

Low cost visual systems that are limited to several thousand calligraphic lights and several hundred surfaces have been successfully used for commercial and military pilot training.

These systems are effective for training activities that involve take-off, landing, and navigation, but because of the limited number of available surfaces, they are not able to produce the scene complexity necessary for advanced training. The problem has been to find a way to extend the training capability of these systems by providing a greater number of training cues, and while preserving the system's low cost.

The best solution found for a low-cost system was to provide a way of adding information to the surfaces used to make up a scene. A change in the intensity of the color across a surface provides a change in position cue, while the modeling and real-time cost is only one surface. This intensity change is produced through the addition of texture. The modulation of the intensity of a color on a surface is provided by table lookup of the intensity change in a memory whose address is a function of position on the surface. Figures 1 and 2 provide contrasting views of the same scene with and without texture.

Texture has been added to the NOVOVIEW SP3T visual system. Working with texture on this system has provided more information on the way models are constructed with texture, as well as the way texture should look and perform.

With the introduction of texture, there have been significant increases in training capabilities of the system. Advances have been made in such areas as low-level flight and over-water data bases that had previously presented special problems for low cost systems.

TEXTURE BUILDING BLOCKS

The basic texture building blocks are the texture patterns, the scale factor for each pattern, and color.

SP3T texture modulates the intensity of the color of surfaces in the ground plane, or in planes parallel to the ground plane. Individual texture patterns are stored in memories and addressed as a map of points. Each of these patterns can be combined together to modulate the intensity of a surface.

The Scale Factor

Data is generated in several different ways, each targeted towards a particular application. The surface description is expanded to include not only color information, but the combination of available patterns to be used to create the overall texture of the surface. The texture patterns are mapped onto the surface according to the scale factor specified by the modeler. The scale factor is used to determine the area on the ground that will be covered by one occurrence of the texture map.

The scale factor is used by the modeler in three different ways:

1. It sets the working altitudes the texture is to be used at.
2. It controls the repetitiveness of the texture patterns.
3. It controls the point at which the texture emerges into the scene.

For example, if a scale factor of 100 feet is specified for a texture pattern, then the pattern will be repeated every 100 feet. The modeler can specify the scale factor for each texture pattern stored in memory, and can combine the texture patterns to create other patterns. The careful selection of the scaling factor for each of the available texture patterns gives the modeler the ability to select the points at which more detail *will emerge. This means the amount of* detail in the scene will change according to the proximity of the viewer to the scene.

In the previous example, the texture pattern was given a scale factor of 100 feet. This repeats the pattern every 100 feet. However, if this pattern is combined with another pattern with a scale factor of 90 feet the combination of the two patterns will not repeat for 900 feet. And if this combination of patterns is combined with a pattern whose scale factor is 800 feet, the combination of the three patterns will not repeat for 7200 feet. The least common multiple of the scale factors is the point at which the combination of the patterns repeats. This is useful in minimizing the repetitiveness of texture patterns.

The Clamp Value

The amplitude of each texture pattern is modulated to provide control of pattern emergence according to the size of the pattern as it varies throughout the image. This function is based on computations that relate the scale factor to the image size projected into model space. The ratio of this distance to the scale factor is called the 'clamp value. This value is calculated independently for each texture pattern. This method of antialiasing has proven to be more useful in controlling texture than any other method in use.[2]

For example, a surface that is textured with two texture patterns, one with a large scale factor A and the other with a smaller scale factor B, will have changes in the overall texture pattern at different proximities to the surface. As this surface is approached, the texture pattern with the scale factor A will be visible sooner than the pattern with the scale pattern B. A clamp value is calculated for each texture pattern's scale factor. The clamp values are applied to the patterns individually. This allows the final pattern to change and emerge as a function of the viewing perspective. The bandwidth of the scene is controlled to allow only the information that is free from unwanted aliasing to be viewed.

Texture Patterns

The modeler selects the texture patterns to be used in a particular data base. Texture patterns that are useful in one application may not be in another. For example, the texture map that is used to create a water pattern is derived from several sine functions, whereas grassy patterns are taken from a fractal-like function.

Fractal techniques have been used to create many "natural looking" scenes, as their application produces an effective randomness in the images.[3] The modeler should select the texture patterns based on the specific application of the data base.

The texture patterns can move in respect to other texture patterns, as well as to the surface they are modeled on. This motion is restricted to the plane of the surface, but the effect of the movement is appealing. Moving two or more texture patterns with respect to one another produces a wave motion useful for a sea scene or in grass, rotor wash in water, or dust trailing a vehicle.

Another variable in applying texture is the use of contrast in the texture pattern. Contrast is distinction between the dark and light areas of the pattern. The contrast of a pattern can be controlled to give patterns that range from subtle to very obvious. But too much contrast may result in an unrealistic scene that could alias inspite of the clamping function described in the previous section. Too little contrast can produce a pattern that is so subtle that it becomes ineffective. The over-all frequency spectrum of a pattern combined with contrast can yield a pattern that is less likely to require antialiasing.

Color

The color of a surface is chosen for its particular application. Texture patterns interact with the surface color, and can create greatly diversified scenes. The same texture pattern that is used to give the appearance of a grassy area on a green surface can be used to create a sand dune effect on a brown or tan surface. The appearance of a scene can be varied by the correct choice of color and the applied texture pattern.

Application of Texture Building Blocks

With the texture building block of pattern, scale factor, and color the modeler can apply texture patterns on surfaces giving height, motion, and closure cues. This gives the modeler on a low cost system more surfaces to use in creating man-made structures or non-ground plane natural objects.

These building blocks have been used to generate data bases that range from water to desert and grass to clouds. Figure 3 is an example of the application of texture in producing a sea scape. The waves are made up of two texture patterns at scales of 271 feet and 1023 feet. These values were chosen to provide for working altitudes of 100 to 1000 feet. At an altitude of 1000 feet, the blue sea color is broken up to provide motion cues. As a pilot descends below this altitude, the smaller pattern emerges, providing closure cues for him. The effect of the emergence of the texture can best be demonstrated on the visual system itself, or in a motion picture. Figures 3, 4, and 5 show the emergence of the texture as the position of the observer changes in three static pictures. The ship is shown to provide a distance reference.

The first view, Figure 3, shows a very large texture pattern from an altitude of 1000 feet. Figure 4 shows the texture as the second pattern is beginning to become visible at about 250 feet. Figure 5 shows the texture patterns from a height of 50 feet, where the viewer can no longer see the effect of the larger texture pattern.

The scale factor is used to specifically tune the data base for its intended application. The scale factors used for a high altitude flight path would be different than those used for low level flight or for maritime applications. The scale factor is incorporated into the data base during the design process and gives a system the flexibility to be used for many design applications.

APPLICATION OF TEXTURE IN DATA BASES

The addition of texture to the NOVOVIEW SP3T *product line has solved many of the* traditional problems that face data base designers; specifically how to incorporate the scene complexity needed for speed and height cues, and at the same time provide enough real world features to make the date base usable and recognizable. While the use of texture greatly simplifies some design areas, there are several new parameters associated with texture implementation that require decisions to be made early in the design process, and that may require possible tuning throughout construction. These parameters include the design or selection of the texture patterns, the size of each pattern, and the height and dynamics of each selected pattern.

As with all other elements of the data base, the texture features must be selected for the intended training requirements. For example, if helicopter take-off and landing training is the intended application, then a texture pattern designed for use at 10,000 feet would be wasted on the low altitude flight *simulation of the helicopter.*

The texture patterns can be selected only after the use of the data base has been established. In the NOVOVIEW SP3 system, the user can choose a total of four texture patterns from a growing library constructed by the supplier on an in-house computer and frame buffer facility. The process of textureselection should include the end-user, whenever possible, to meet the specific needs of the data base design.

The choice of the texture patterns must be evaluated with the combination of the available scale factors and their application to the various colors to determine what is most suited for the particular training needs. Fortunately, system architecture readily allows for the substitution of different patterns or alterations in pattern size during the construction process.

Once an initial set of texture patterns has been selected, the allocation of system resources can begin. Using texture for natural features and reserving the edges and faces (and light points) for cultural objects is the standard approach. The classic example of this configuration is the ship in Figure 4, where all of the system capacity except the sky and water surfaces is dedicated to the ship and wake.

Many applications of texture are not as clear cut as the ship example. With an extensive use of texture in sky and cloud features, a pilot will still require a frame of reference. This could be provided by cross checks with airspeed and altimeter instruments that would take place in the real aircraft. The advantage of texture is that the frequency of these cross checks is much closer to real world flying conditions. The frame of reference can be established by having items of know size and orientation along the flight path. When system capacity allows for it, reference features should be included in the data base design.

Natural Scene Elements

Texture's most obvious application is to large homogenous areas such as ocean, desert, snow, and sky/cloud scenes. With these fairly simple cases, there are still considerations to take into account. If a pattern is too small or has too much contrast, the repetition of the pattern can become obvious and distracting. This can be solved by tuning the scale of the pattern or choosing a less regular one, such as shown in Figures 6 and 7.

Attention must also be given to the texture chosen, so that it doesn't supply too many cues. The real world task of flying at low altitudes over large homogenous areas like water or snow can be very hazardous because of disorientation and optical illusions. If the textures creates a scene that is too solid, negative training could result. The dynamic capabilities of the texture can be used to avoid this problem. An effective approach is to move each of the texture maps independently. In the case of an over-water flight, the same "wave" pattern can be loaded into two of the available texture maps. The patterns can then be moved in opposite directions at the same speed. The constant interaction between the two patterns creates a heaving effect. This same method can be used to produce blowing snow or sand.

Sky and cloud decks are also obvious applications of texture. On clear days, the sky will normally have some clouds that can provide turning and pitch cues when the ground is not visible. A subtle texture pattern applied to the sky and placed at an altitude high enough to not be penetrated has a realistic appearance and can provide turning cues. An example of this is shown in Figure 8. Cloud layers, as shown in Figure 9, require a more definite pattern. Some of the available texture patterns could be applied slightly above and below the selected cloud ceiling or cloud top. This provides parallax cues that have a three dimensional appearance. The ground texture may be simultaneously used above the horizon with a different (usually larger) scale factor. When selecting ground patterns, their application to the sky and clouds may be a consideration.

Texture can also be effectively used on small areas. As shown in Figure 10, the texture pattern is used to simulate a metal mesh. This pattern is elevated to provide effective parallax cues when viewed with other patterns in the surrounding area, such as the sea surface pattern.

Cultural Scene Elements

The use of texture on man-made or man-induced scene elements is not as frequent as on natural ones. When applied to cultural objects, it tends to be used on relatively small areas. Figure 11 shows the use of a small scale fractal pattern to simulate the surface and expansion cracks on a concrete runway. This is an effective speed cue during landing and taxi training. Although this is a useful application for texture, these patterns are limited to the small areas they were designed for. Also, such small areas are more likely to alias when close to eyepoint. The interaction of the pattern size and the clamping function is used to maintain a solid scene. Because of this, in an application where several different small patterns are required in different parts of the data base, a management technique may be used that brings in a new pattern as each area is approached. This allows the combination of several patterns to be applied to the overall scene, including the sky, while applying only one pattern to small dedicated features.

SUMMARY

The overall implementation of texture in the NOVOVIEW SP3T has allowed experimentation in areas not previously associated with low cost systems. The use in scene elements such as smoke, dust clouds, and ship wakes are examples of the successful application of texture. The application of moving texture on static surfaces, or static texture on moving surfaces, and texture moving simultaneously provide a wide variety of effects. Different texture patterns, static or dynamic, when applied to adjacent surfaces of the same color, produce results similar to the shading effects that are associated with more expensive systems.

The addition of texture generation capability to a low cost system greatly increases the application range of that system. Not only does texture enhance the simulation properties of the system, by producing images that more closely resemble terrain, sky, and cultural objects, but these enhancements are at a relatively low cost to system overhead. With the antialiasing properties available, texture allows the proper emergence of detail, making the closure to objects more realistic.

Originally, texture was conceived as a way of breaking up surfaces to provide the viewer with more information about surface contours, but the texture generating capabilities achieved through experimentation and problem solving have proven texture to be a much more valuable tool.

The application of texture, within the structure of a low cost system, provides the end user with a data base that simulates more natural appearing scenes and provides extensive training cues not previously available in such a system.

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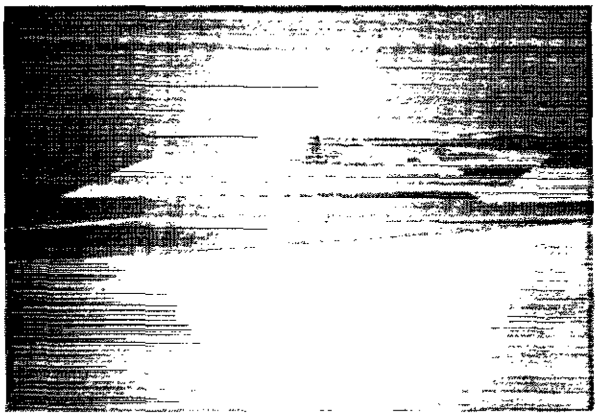

Figure 1 - Norfolk without Texture

Figure 2 - Norfolk with Texture

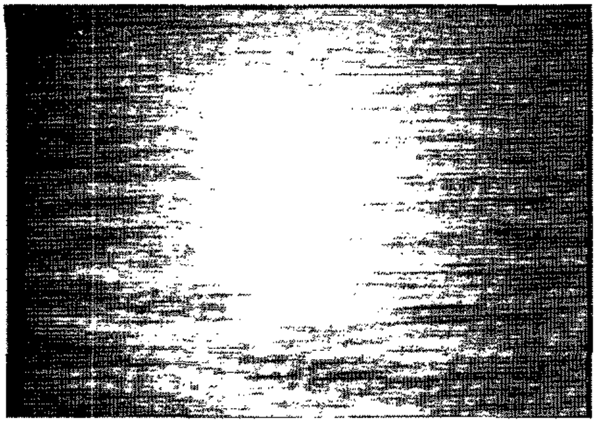

Figure 3 - Ship in Textured Sea at Altitude of 1000 Feet

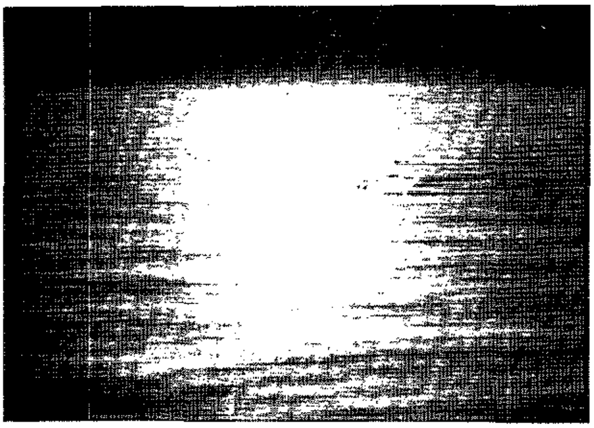

Figure 4 - Ship in Textured Sea at Altitude of 250 Feet

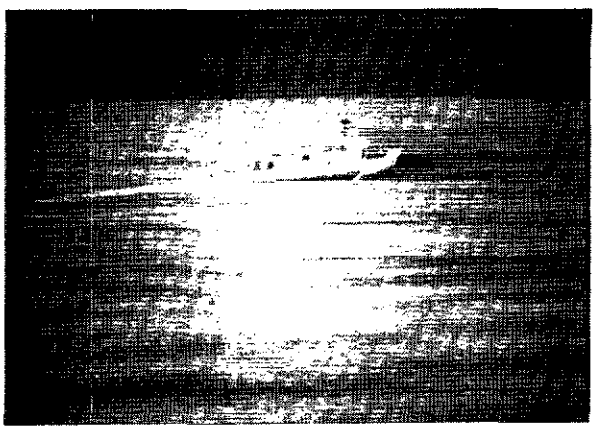

Figure 5 - Ship in Textured Sea at Altitude of about 50 Feet

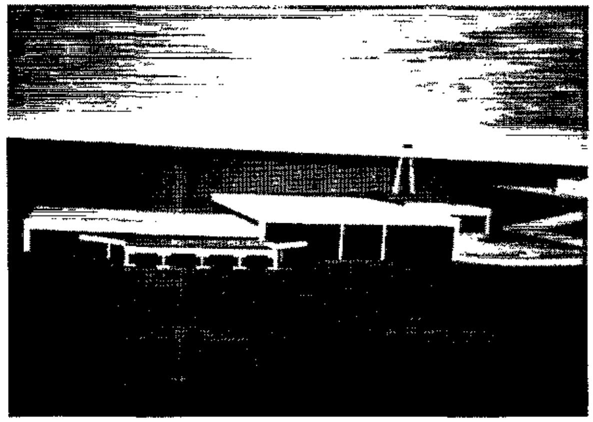

Figure 6 - Conrow Airport with Grassy Texture

Figure 7 - Desert Scene with Tanks

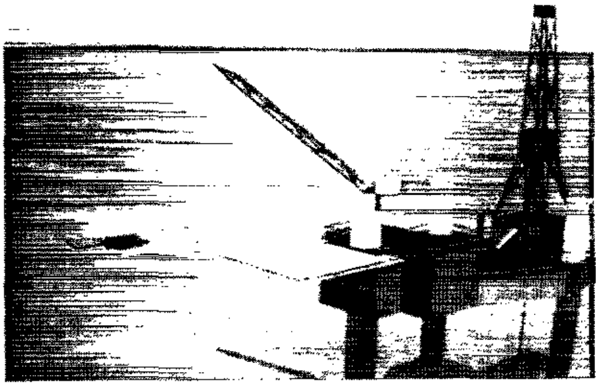

Figure 8 - Texture on Water Surrounding an Oil Rig

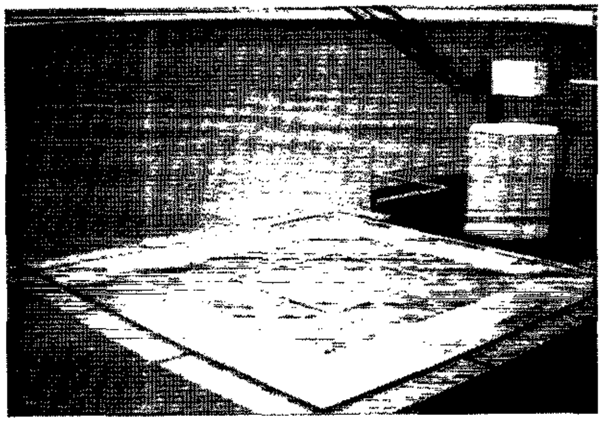

Figure - 10 Texture on Two Heights; the Water and the Wire Mesh

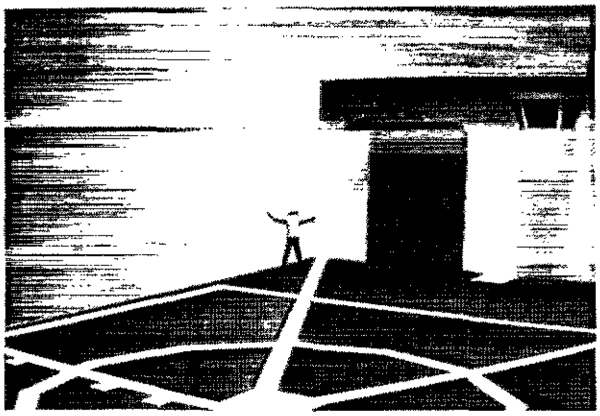

Figure 9 - Cloud Texture Above Landing Pad on Ship

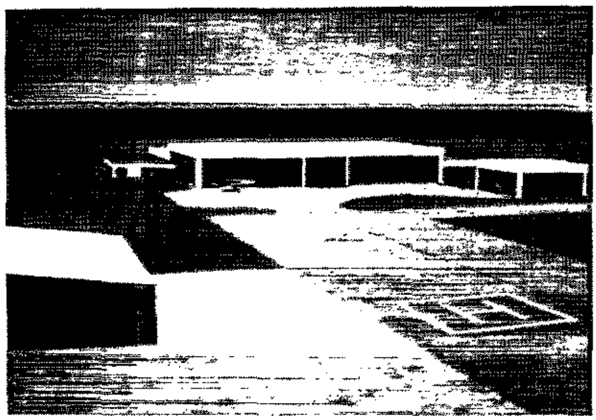

Figure 11 - Cement Texture with Runway Cracks