CELL TEXTURE - ITS IMPACT ON COMPUTER IMAGE GENERATION

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ABSTRACT

Since their inception many years ago, all practical computer image generators have been based on producing a representation of the scene being simulated by approximating all scene features with "faces" (polygon bounded planar segments). The lack of visual fidelity in all early systems has led to continuing effort to reduce the cost per face so a greater number of faces, more closely approximating the simulated scene, could be used.

Recent developments which allow patterns to be successfully overlaid on faces promise to radically change the nature of the business. The patterns may be derived from digitized photographs, random numbers with the desired statistical characteristics, mathematical functions, or from direct input by the modeler. This provides very high scene fidelity at relatively low face counts. The user now has a choice. He can use the increased scene fidelity with conventional face capacities to address visual cuing tasks never before successfully achieved, such as nap-of-the-earth helicopter flight. Other requirements may best be met with low-face-count (and hence low-cost) systems along with the new photographic quality capability to provide more realistic cues than current high-cost systems.

This paper describes the performance of General Electric's current application of this technology (known as "cell texture") in its new COMPU-SCENE IV image generator product series.

BACKGROUND

CIG Evolution

Real-time Computer Image Generation (CIG) systems have for the most part used planar segments (faces) to approximate the environment to be displayed. This leads to linear computations which requires far less hardware than necessary for higher-order surfaces. In early systems each face was a constant fixed color. Sun-shading was developed, modulating the intensity of each face as a function of its angle relative to the source of illumination. With sun-shading, faces still had color and intensity the same everywhere on the face. Smooth-shading provides for linear variation of intensity along a face. Its first real-time implementation was on the ASPT system, delivered in 1974, where it was applied to implement the Gouraud curved surface simulation algorithm, as well as other effects.

Stripe Texture

With any combination of the above, faces are still unnaturally smooth. Further, when a viewer gets very close to a large face so that it is all he sees, there is a complete lack of visual cues. Stripe texture provided a breakthrough in overcoming these limitations. It allows patterns of parallel stripes with varying orientation to be overlaid on a face. The texture generator generates modulation numbers from these sets of stripes. These may modulate the face intensity directly, or they may be applied to a translation memory with thresholding action which obscures the stripe effect while still providing texture cues. The effect achieved would require millions of edges and faces to duplicate by conventional approaches, yet is produced with feasible hardware by a single texture generator. An early version of stripe texture was present on a system delivered to NASA in 1964. It was quite limited in the effects that could be produced, it suffered from scintillation in the distance and, possibly most serious, it was limited to use with display devices on which raster could be rolled. Modern stripe texture, free of artifacts and with no raster orientation limitations, was developed in 1976 and operational on a real-time system in 1978. Figure 1 shows a scene with this stripe texture.

Cell Texture

With stripe texture, each entry in a texture map memory provides control over a stripe-shaped region on a face. Cell texture carries this concept a step further. Each entry in the memory provides control over a region on a face defined by a square or a rectangle -- a "cell". If the cells are made small, and the memory contents come from digitizing a photograph, then the photograph is mapped onto a face. The tiger on the aircraft tail in Figure 2 is an example of this use of cell texture capability.

The basic concept of cell texture, cell-by-cell control of an image on a face, has been known and under investigation for some time. Many scenes and sequences generated nonreal-time have been produced. A great deal of development was required to produce the high quality real-time scenes being generated by the COMPU-SCENE IV prototype system now operational in our laboratory. Development of algorithms and hardware to perform all required computations in real-time was required. Memory access for a number of parallel paths had to be implemented in an efficient manner. Gradual level-of-detail blending to produce dynamic sequences without artifacts was developed. Transparency, translucency, image boundary effects, large-area tiling, techniques for obtaining cell map memory contents to produce optimum results -- all these were successfully solved to achieve advanced object simulation. Reference 1 discusses in some detail many problems encountered and the solutions to these problems. This paper will concentrate on applications of the technique and comparisons with earlier technology.

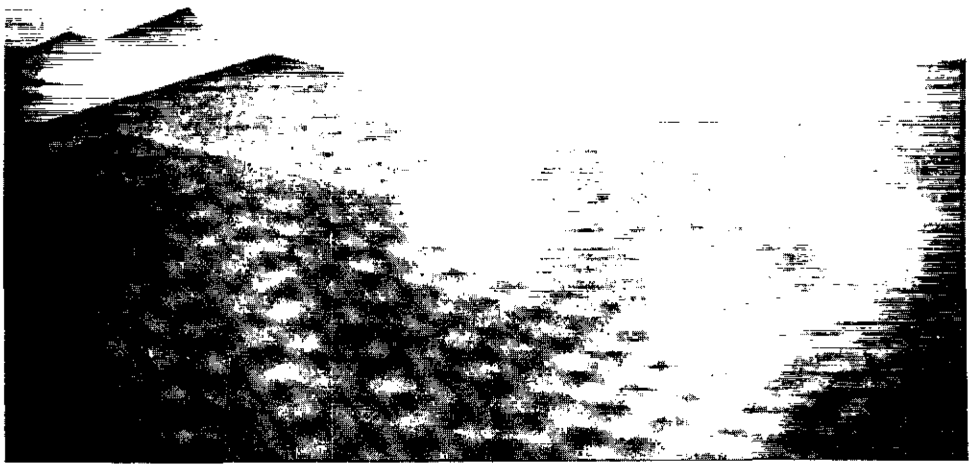

Figure 1. Scene with Stripe Texture

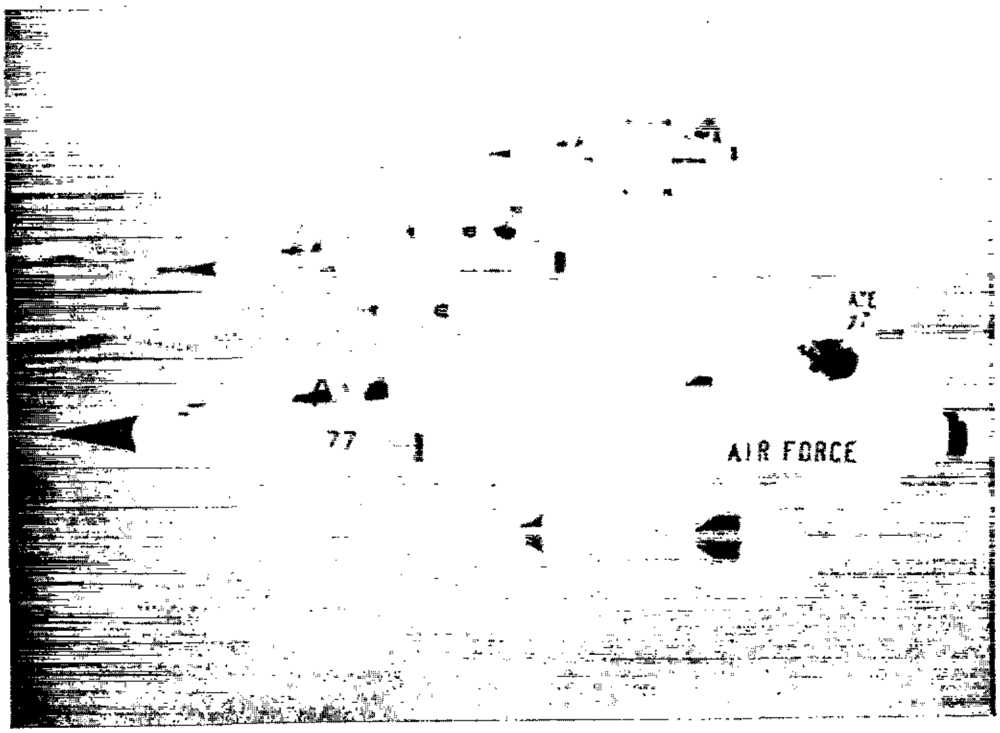

Figure 2. Cell Texture Used for Clouds and Tiger

ADVANCED OBJECT GENERATION APPLICATIONS

Tree Simulation

Figure 3 shows trees modeled with 40, 60, and 800 faces without cell texture; and modeled with 16 faces using cell texture. It is important to note that the cell-texture tree is not a "billboard" tree. It is a three-dimensional tree that provides valid three-dimensional cues as one flies around or over it. It was stated above that cell texture gives us the choice of using the same number of faces and achieving far superior results, or achieving comparable results with far fewer faces. This illustration shows that was an understatement.

Same Face Count, Higher Realism

Figure 6, modeled from 860 faces, contains trees, distant mountains, and a stripe-textured ground surface. Figure 7, employing cell texture, contains similar features, but with drastically improved realism, using only 786 faces. This illustrates a choice at one end of the trade off spectrum.

Face Reduction

Figure 8 shows a rather spartan view of a couple of trees, a tank, stripe-textured fields, and background mountains. It was produced with 153 faces. Figure 9, with only 32 faces, is a comparable scene taking advantage of the realism provided by cell texture. It illustrates the opposite end of the trade off spectrum.

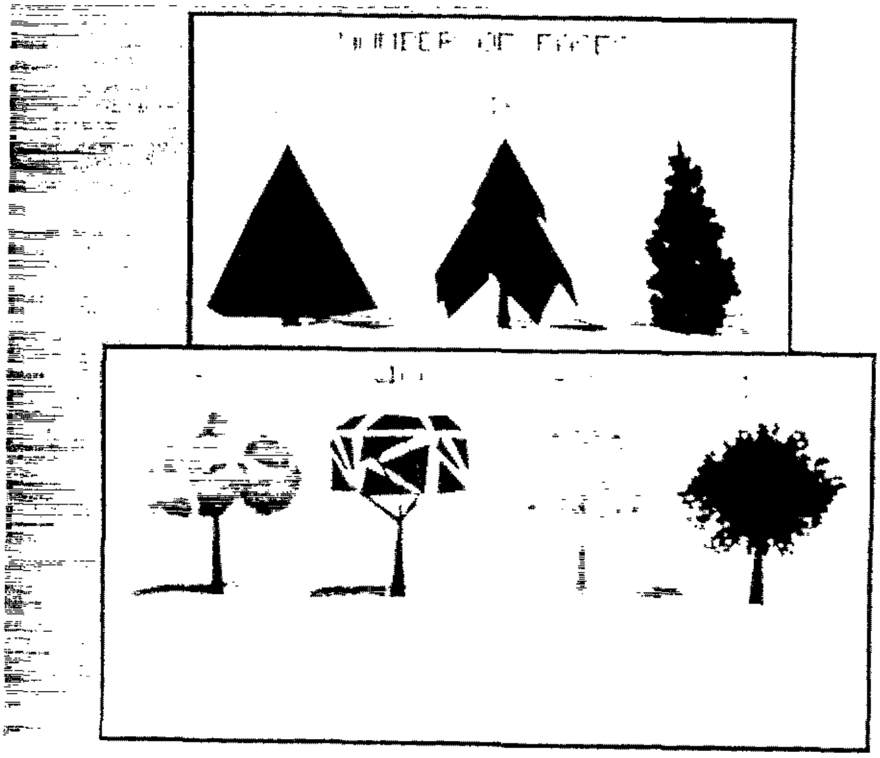

Figure 3. Trees: With and Without Cell Texture

Layering - 3-D Brush and Clouds

One very effective tool for use with cell texture is selective transparency. This designates that all texture modulation values in a specified range will cause the portions of the face on which they lie to be transparent. Now assume a cell memory with a continuum of values. Apply this same map to three parallel surface faces; say, three feet apart. Use different threshold values so that the transparency increases for the upper faces. The effect is that of low-growing brush. When seen dynamically while flying at low altitude the three-dimensional effect is powerful and valid. The sketch on Figure 4 can only hint at the effectiveness.

The same layering technique can be applied to production of cloud layers. This is illustrated in Figure 5. This figure also shows a more conventional application of cell texture to produce the camouflage paint on the F-5.

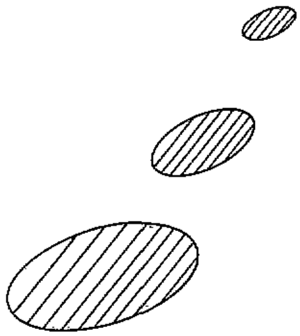

Figure 4. Three-dimensional Brush With Cell Texture Layering

Figure 5. Cloud Layers

Multi-Cell-Texture Application

Figure 10 shows a scene in which every feature takes advantage of cell texture. Note the realistic tire marks on the runway, continuous across the boundaries of runway stripes. The "background" portion of the runway, under the stripes, has muted texture which will provide motion cues even where tire marks or stripes cannot be seen. The hangars have cell texture applied to the outer walls to simulate corrugated metal construction. Ground texture, both on the flat terrain and on the mountains, is applied in a manner which has been discussed earlier. Trees can be seen in the background. If the pilot chooses to fly close to them he will see that they are fully-formed, realistic trees. Finally, the sky exhibits the specified percent cloud cover, produced using cell texture with controlled translucency.

COMPU-SCENE IV

The new COMPU-SCENE IV series of CIG systems contain many innovations in addition to cell texture. VLSI is applied to improve performance and reduce cost. New algorithms have reduced artifacts almost to zero level. New overload management algorithms prevent scene breakup when overloads abruptly occur. Nevertheless, from the standpoint of the scene modeler, the training instructor, and the user, the new advanced object generation employing cell texture is the most visible innovation, and probably the most valuable in providing effective visual cues for training.

THE FUTURE

Research effort is continuing to make cell texture even more useful. We expect to be able to produce fluttering leaves, flickering flame, or billowing smoke. Movies on a face are possible. Algorithms to produce valid cell texture on curved surfaces--not just on planar faces --are being developed. The goal of this effort is that no needs of the training community for realism shall go unmet.

REFERENCES

(1) Bunker and Economy, "Advanced Video Object Simulation", Proceedings of IEEE 1984 National Aerospace and Electronics Conference (NAECON 1984), Dayton, OH, May 21 - 25 1984; pp 1065 - 1071.

ABOUT THE AUTHORS

Dr. W. Marvin Bunker is a Senior Consulting Engineer in Advanced Technologies Engineering at the General Electric Company in Daytona Beach, Florida. He received a BSEE from the University of Oklahoma and an ME and Ph.D. from the University of Florida. He is currently active in research and development on computer generation of images for real-time visual scene simulation in training systems. Marv has authored papers in areas of simulation, computer techniques, and circuit theory. In addition to his industrial activities, he has taught at several universities.

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Dr. James F. Harvey was formerly Manager, Advanced Simulation and Training Systems at the General Electric Company in Daytona Beach, Florida. He attended the University of London where he graduated with honors in Chemistry and received a Ph.D. in Chemistry. He was Technical Director of the Naval Training Equipment Center in Orlando, Florida prior to joining GE. His responsibilities at GE included long-range planning and direction of technical effort leading toward continually more advanced system. Jim is currently President of Eagle Technology of Arlington, Virginia.

Figure 6. 860-Face Scene Without Cell Texture

Figure 7. 786-Face Cell Textured Scene

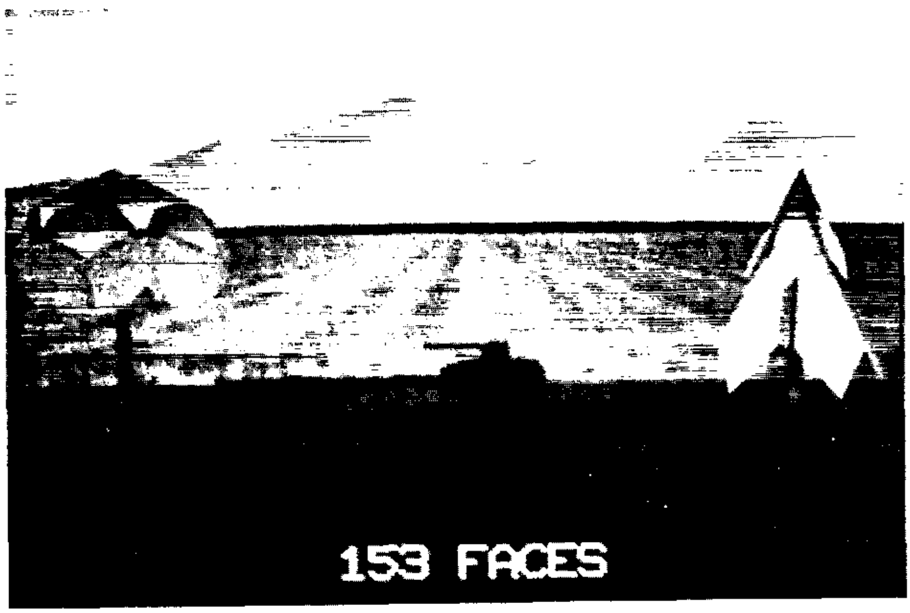

Figure 8. 153-Face Non-Cell Textured Scene

Figure 9. 32-Face Cell Textured Scene

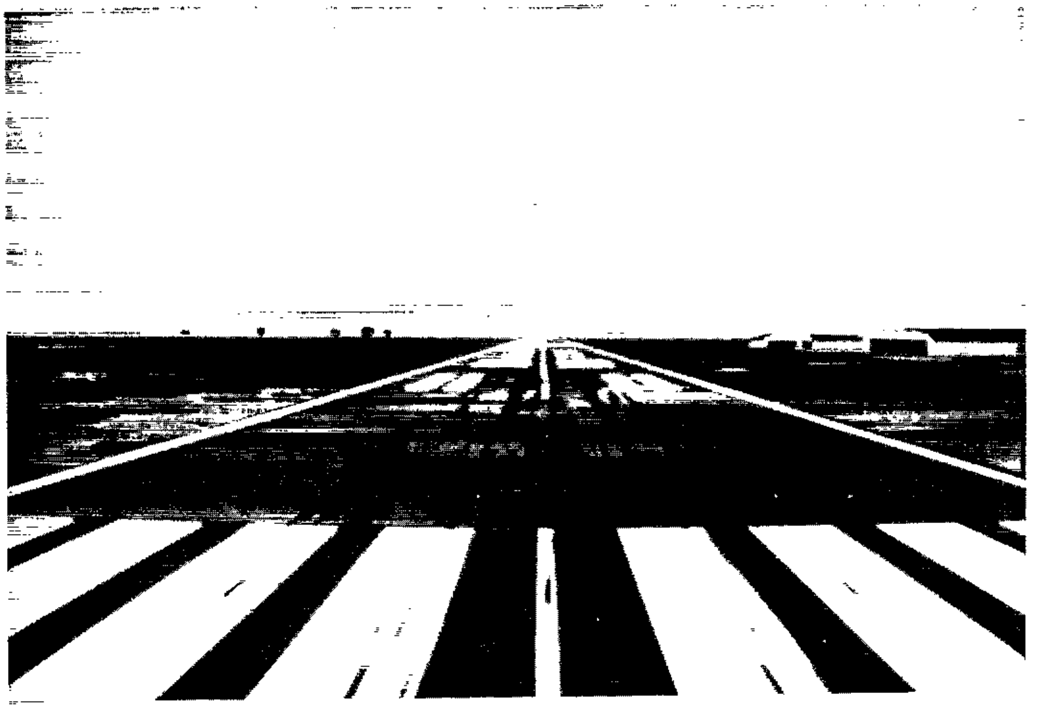

Figure 10. Cell Textured Runway Scene