MAKING CLOUDS

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ABSTRACT

The increasing fidelity of visual simulators has created a requirement for realistic images of natural phenomena such as clouds. In the GBU15 part task trainer, cloud images were used to simulate the obscuration of the sensor's field of view during simulated training missions. Obtaining cloud images that met the fidelity requirements of the trainer was difficult. The cloud images had to look realistic, yet have a predefined distribution over a large area, and the images could not contain a background. Three methods for obtaining the cloud images were evaluated. The methods were photography, painting, and Computer Image Generation (CIG). The CIG method was chosen for the GBU15 part task trainer because it allowed control of cloud distribution, shape, and density, and it generated images at the required resolution and without a background.

INTRODUCTION

The GBU15 part task trainer required a database of cloud images to obscure the sensors field of view during simulated training missions. Several methods for creating the image database were evaluated before a simple Computer Image Generation (CIG) method was selected. A brief overview of the GBU15 part task trainer will explain the requirements placed on the cloud image database. Then the tradeoffs between the alternatives for creating the database will be described, followed by a description of the selected CIG method.

GBU15 PART TASK TRAINER

The GBU15 (Guided Bomb Unit) is a remotely guided bomb that is released from an aircraft and then guided to its target by a Weapons Officer (WO) in the back seat of the aircraft. The WO guides the bomb to its target by watching the video transmitted back to the aircraft from a TV camera in the nose of the bomb. The GBU15 trainer simulates the WO's video display using photographic images of the target and the surrounding terrain. As a student "flys" a mission in the trainer, the video image is rotated, translated, and expanded to simulate the path of the bomb. The training system maintains a high visual resolution on the display by switching image resolution planes during the simulated mission (figure 1). When the expansion of the image would cause a noticeable degradation in display resolution, the trainer automatically switches to the next image resolution plane. The first image resolution plane covers the largest area and is used during the initial phase of the mission. Subsequent resolution planes cover smaller regions at higher resolutions (figure 2). Each image resolution plane is many times larger than the resolution of the display to allow the student a range of motion in the path of the bomb.

One of the training requirements was the ability of the instructor to obscure the students view of the target with a simulated cloud deck (figure 3). To simulate the cloud deck a database of cloud image resolution planes had to be created that covered the same regions as the photographic resolution planes.
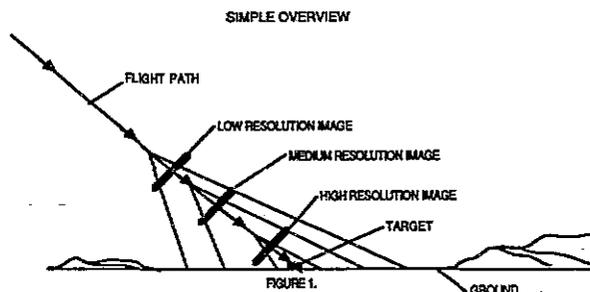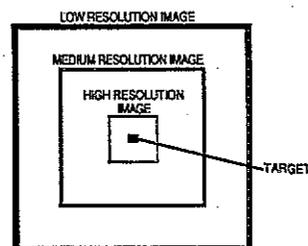

FIGURE 1.

FIGURE 2.

FIGURE 3.

TRADEOFF

Three alternatives were evaluated for creating the database of cloud image resolution planes:

1) Photography.
2) Painting.
3) Computer Image Generation (CIG).

The CIG method was chosen because it produced the best results without the problems inherent in the other methods. The details of the tradeoff, including a description of the evaluation procedure and the resulting pros and cons follows:

Photography

Evaluation procedure:

- Take aerial and ground photographs of real clouds.

Pros:

- Inexpensive if taken at the same time as the terrain photos.

- Guaranteed realism.

Cons:

- The cloud pattern desired is not always available and is dependent on weather.

- Difficult if not impossible to eliminate background from semi-transparent clouds.

- Could not mosaic images since clouds move and change shape. Extremely high resolution required for a single photograph.

- 3D shape of clouds produced almost total occulting of the background at the low camera angles required.

Painting

Evaluation procedure:

- An artist painted a small picture of cumulus clouds and a section of a large mural of clouds. The paintings were photographed and then the photographs were digitized.

Pros:

- Realistic images, with good cloud distribution.

- Cloud patterns limited only by imagination.

- Shares none of the cons of the photographic approach.

Cons:

- The airbrush spray of white on black produced visible dots rather than shades of gray.

- A Brush would produce stroke marks.

- Each cloud pattern requires a whole new painting.

Note:

- This method could be significantly improved if the airbrush painting was digitized then smoothed using a digital filter.

CIG

Evaluation procedure:

- Generated an image showing a perspective view of a flat cloud deck using a fractal based CIG method.

Pros:

- The sample image looked realistic with continuous shades of gray.

- Once the method and program are in place, many cloud patterns can be generated quickly.

- The method can be tailored for desired effects (e.g. control of cloud density and distribution, and the edge of database won't cut through the middle of a cloud).

Cons:

- Flat cloud deck, clouds do not occult each other.

CIG METHOD

The CIG method was used to create the database of cloud image resolution planes in three steps:

FIGURE 4

1)   A three dimensional terrain elevation database was created using Fractals.

2)   The terrain database was shaded to create top down images of a cloud deck. Figure 4 shows a small section of the cloud deck.

3)   The top down images were resampled to create the perspective views and resolution planes.

The details of the three steps are as follows:

Terrain Database

The terrain elevation database was created using a method based on L. Carpenter's[*] algorithm for creating fractal terrain. The algorithm divides the terrain into smaller and smaller tiles and calculates new elevations for the corners of the subdivided tiles (figure 5). The steps in the algorithm are as follows:

1)   Elevation points are entered manually at the corners of the largest tiles. These elevation points control the overall shape of the cloud distribution.

2)   The elevations at the center of each tile and at the midpoint of its sides are calculated based on the neighboring elevations.

3)   Random offsets are added to the calculated elevations, and the results are stored as the new corner points of the subdivided tiles.

4)   Steps 2 and 3 are repeated for the next (smaller) tile size, until the elevations at the corners of the smallest tiles have been calculated.

For step one (1), the elevations values are chosen to create the desired overall shape of the cloud distribution. This includes setting the elevation values along the outer edges of the database to zero, so that clouds will fade out smoothly, and not stop abruptly at the edges of the database.

For step two (2), the new elevations were calculated using parametric surface patches. This maintained the simplicity of a regular grid structure and compatibility with Defense Mapping Agency (DMA) data, while eliminating the visual artifacts caused by the regular nature of the underlying grid structure. Each surface patch was defined by the sixteen elevations at the corners of the current and neighboring tiles. The elevations at the middle of each tile, and the midpoints of its sides were calculated from the surface patch. A simpler, more common technique is to calculate the new

elevations using linear interpolation from the tiles corner points. As shown in figure 6, there can be a large difference in the elevations calculated by the two methods. The amount of additional computations required for the surface patch were reduced by optimizing the equations for this application.

For step three (3), the random offsets were calculated by multiplying an elevation offset by a pseudo-random number between 1 and -1. The size of the elevation offset was reduced linearly with the size of the tile. This created terrain that produced the most realistic cloud images. Reducing the size of the offset at the same rate as the tile size models the 1/F spatial frequency distribution found in nature. The 1/F frequency distribution of natural shapes has been demonstrated[**] in images of terrain and clouds by R. Voss[**].
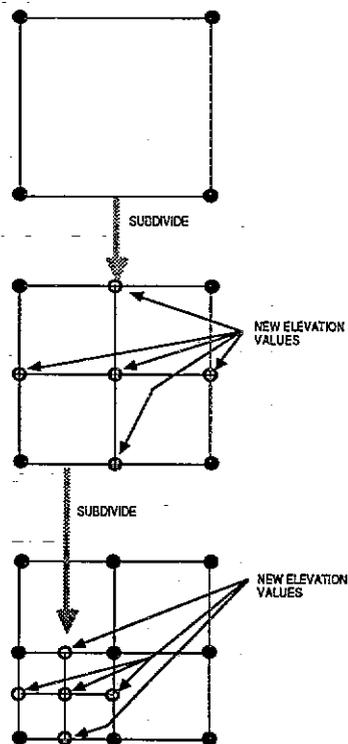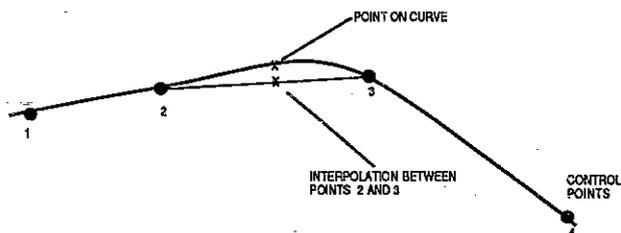

FIGURE 5.

Figure 6

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The method for creating the terrain database is a simple example of a general class of algorithms for generating natural shapes. The algorithms use a stochastic process guided by a system of rules. Realistic images of trees, grass and fire[#] have been created using more complex examples of this class of algorithms.

Top Down Images

To create the top-down images of clouds, the terrain elevation database was shaded as shown in figure 7. An upper and lower elevation threshold was selected. Elevations below the lower threshold were assigned black, and elevations above the upper threshold were assigned white. The elevations in between were assigned shades of gray, depending on their relative position between the upper and lower thresholds. Adjusting the lower threshold controlled the open space between the clouds, while adjusting the distance between the upper and lower thresholds controlled the clouds translucency. The result was a top down image with a shaded pixel for each elevation value in the terrain.

Perspective Views

The perspective projections were created by resampling the top down images. The large database of top down images was managed by creating the terrain and the corresponding top down images in 1024 by 1024 pixel blocks. Breaking the database into blocks had several advantages during the resampling process:

1) Only the blocks in each resolution planes field of view were processed by the resampling algorithm.

2) Blocks could be prefiltered (the resolution of the blocks was reduced by averaging pixels) to reduce the amount of processing during resampling.
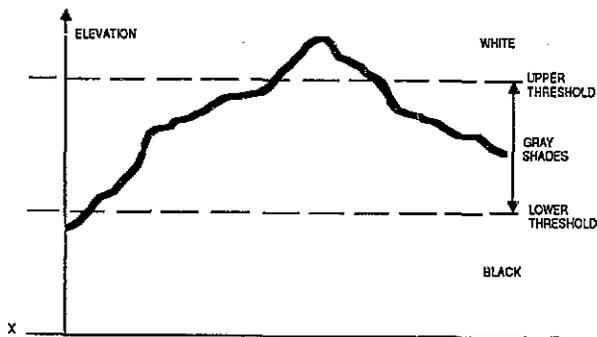

Figure 7

CONCLUSION

Using a CIG method to generate the database of cloud images solved several problems inherent in the alternate methods of photography or painting. The CIG method produced realistic images and allowed control of the distribution and density of the clouds. Also the CIG method allowed the database to be created and managed in convenient 1024 by 1024 pixel blocks. The only disadvantage to the CIG method was that it produced images of a flat cloud deck.

The fractal terrain/cloud CIG method used to generate the cloud images was a simple example of a rule based system guiding a stochastic process to generate natural shapes. This general class of CIG algorithms has tremendous potential for improving the realism of images used in visual trainers/simulators while reducing the effort required to create the databases.

REFERENCE

* Carpenter, L., A. Fournier, and D. Fussel, "Computer Rendering of Stochastic Models", Communications of the ACM, 25(7), June 1982, pp. 371-384.

** Voss, R., The Fractal Geometry of Nature, by B. Mandlebrot (Freeman 1982), pp. C8-C15.

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ABOUT THE AUTHORS

Richard Hopkins is a lead software engineer at Honeywell Training and Control Systems Division in West Covina, California. He holds a MS in Computer Science, and a BS in Physics. He is currently working on the prototype for Honeywell's next generation of visual systems, and has also supported the development of the GBU15 trainer which uses the current generation visual system. His experience includes over 10 years of software development and systems design for flight simulators, and for special effects in film and video.

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