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Three-Dimensional Perspective Visualization

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Abstract

It has been demonstrated that image processing/computer graphic techniques can provide an effective means of physiographic analysis of remotely sensed regions through the use of three-dimensional perspective rendering. This talk will explain the methods used to simulate and animate three-dimensional surfaces from 2-dimensional imagery and digital elevation models. A brief historic look at JPL's efforts in this field and several examples of animations, illustrating the evolution of these techniques from 1985, will be shown. JPL's current research in this area will also be discussed along with examples of technology transfer and potential commercial application. The software is part of the VICAR image processing system which was developed at the Multimission Image Processing Laboratory of JPL.

Narrative Talk Outline

I. Historic Perspective from 1985: How and Why we began work in 3-dimensional perspective rendering (3DPR).

A. JPL's Atmospheric Parameter Mapping Task were producing several 2-dimensional time series animations of several atmospheric parameters derived from satellite data.

B. A primary visualization challenge was to simultaneously display multiple parameters like percent cloud cover and cloud top barometric pressure.

C. The Animation "Topo Follies" by JPL Scientist Dr. Mike Kobrick was produced in 1985. This was the first 3DPR animation utilizing Kobrick's original ray casting program. It simultaneously displays LANDSAT multispectral image data with a digital elevation model used as the third dimension "Topo Follies" depicts a short flight around and through Death Valley California.

D. The above technique was imported into the VICAR (Video Image Communication and Retrieval) image processing software system, developed by JPL to support planetary exploration, and applied to cloud cover and cloud top barometric pressure data. The inverse of barometric pressure was used as the third dimension. Several 3DPR animations of cloud cover and altitude have been produced.

II. Improvement of 3DPR capabilities: Improvements have come in 3 categories. The first to be dealt with was ease of use (A thru D below), next came speed of rendering (E below) and finally the quality of the rendering (F & G below).

A. Original FORTRAN code from Kobrick required fixed input and output image sizes along with pre-computed "flight" parameter tables.

B. The VICAR version of render was re-written in C and allows variable sized inputs and outputs. (Largest inputs and outputs used to date are: 20,000 lines by 14,000 samples input, and an output image size of 3100 lines by 4200 samples). There are no set size limits.

C. Interactive "Flight" parameter selection software written: The program 3DI (three-dimensional interactive) is used to select the viewing parameters. 3DI graphically represents the parameters on a workstation display monitor and allows the user to change them interactively. Once satisfied with the changes, the user can preview the resulting 3DPR image as calculated from the actual input images to be used for the animation. After previewing, the parameters and/or previews may be saved for later application. 3DI is not used to generate the movie frames because it works on a scaled down version of the original input image and elevation data. This is done to greatly reduce the amount of processing speed needed to generate the previews.

D. "L. A.: The Movie" was the result of the first application of 3DI and VICAR render. It's a 2 minute and 6 second flight simulation over the Los Angeles area using LANDSAT Thematic Mapper data and digital terrain elevation data.

E. The "Pyramid" rendering algorithm: A major speed up. The new algorithm uses a multiple resolution input image pyramid to improve rendering speed and quality. One scene, rendered from a LANDSAT mosaic of California, took 4 hours and 44 minutes to render before the pyramid algorithm was implemented; the same scene took only one minute and 30 seconds using an eight resolution level input data pyramid. This represents a speed-up of 189 times. In addition to the speed up, the animation quality was greatly improved by reducing high frequency aliasing artifacts (sparkle).

F. Multiple Rays per pixel: For each pixel in the output image, several rays (instead of just one) are extended from the "camera" through the output pixel and lengthened until they intersect the surface defined by the elevation data. The rays, in effect, form a cone that intersects with the surface. The area inside the "cone" on the input image are averaged to produce the value of the output pixel. This technique also greatly reduces the amount of high frequency aliasing artifacts (sparkle) which results in greater visual clarity.

G. Field Rendering: Doubling the number of computed fields per second nearly eliminates gitter. A standard NTSC television signal is comprised of 30 frames per second. Each frame is comprised of 2 interlaced fields. By computing and recording the 60 interlaced fields per second instead of the 30 frames you can virtually eliminate the appearance of objects gittering on the screen. This improvement has been incorporated into the 3DPR software.

IV. Current Research: Along with continuing to improve the ease of use, speed and quality of the 3DPR techniques, we are adding additional capabilities to our 3DI program. These capabilities include the ability to "interactively fly" over very large data bases under joy stick control and to interactively perform basic analytical functions on user selected areas of the 3DPR images being displayed. (The level of interactivity will be, in part, a function on the workstation being used.) Volumetric visualization of oceanographic data is also currently being pursed in the 3DI context. This work is being accomplished under UNIX in an X-windows environment.

V. Initial Technology Transfer: JPL to Syracuse Research Corporation (SRC). A task to transfer the 3DPR capability described above to private industry has begun. SRC is funding a portion of the current visualization research taking place at JPL in return for a license to utilize the prototype technology developed for commercial applications. The benefits to JPL are two fold. First, it provides additional funds for research and second, SRC becomes an active participant in the research, through their own independent development, and exhaustive testing of the new capabilities.

VI. Conclusions: We've only just begun. Even though we've been working in the area of 3DPR since 1986 (at less than a one person per year effort) we only recently have received funding to proceed with our planned improvements at a three-person per year level for at least 1991. We believe adding interactivity, volume visualization and a built in analytical capability, will make the three-dimensional perspective rendering techniques described here a valuable contribution to NASA's goal of providing scientists with the technology they need to understand some of the Earth's problems.