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ON THE FUTURE: ENGINEERING THE APPEARANCE OF CYBERSPACE

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> Cyberspace. A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts . . . A graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receding . . .
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> —William Gibson, *Neuromancer*

INTRODUCTION

This chapter derives from an invited paper delivered to the Computer Graphics International Conference in Calgary, Canada, in 1999. It makes a nice epilog to this book, as it points out that procedural methods are key to the future of the human-computer interface. Or so the author would have us believe . . .

It was written before the MojoWorld project was begun in earnest. MojoWorld version 1.0 marks the first step toward the kind of procedural cyberspace advocated here. One of the most interesting things about MojoWorld is that it shows clearly, in one application program, the engineering gap that remains to be closed between what we can do in real time today, as illustrated by MojoWorld's real-time renderer, and what we want to do in real time in the future, as illustrated by MojoWorld's photorealistic renderer. The imagery generated by the real-time renderer is a pale approximation to that of the photorealistic renderer, which is in turn "good enough" to generate the alternate reality that is cyberspace. "Good enough" is, of course, a value judgment, and everyone is entitled to his or her own opinion about it. And I've started—but was too impatient to finish—a MojoWorld rendering that would have taken about 100 days to complete. (Granted, that was at a resolution of 15,000 by 10,000 pixels, far higher than required for a useful interactive cyberspace.) When we can get the quality of MojoWorld's photorealistic renderer in real time at a resolution of 2000–4000 pixels on a side, we'll have the environment that will serve as cyberspace. Then we'll face the challenge of representing the data that we go into cyberspace to access in real time as well. Clearly, we have some years of work cut out for us to get from here to there.

It's interesting to keep in mind that what we're ultimately up to with MojoWorld is not simply generating realistic and beautiful imagery but a transparent user interface.

Gibson's definition of cyberspace in a science fiction novel in 1984 was remarkably prescient. Today's World Wide Web is the beginning of the organization of, and access to, the data Gibson refers to, but as a visualization it is embryonic and, so far, unremarkable—it is simply hypertext, not the immersive environment envisioned by Gibson. The fact that we are constrained to such tame representation is primarily attributable to the two separate problems of transferring large amounts of data rapidly and of computing high-quality imagery in real time. When we achieve near-instant access to the requisite data and the capacity to generate detailed immersive, interactive visuals on the fly, cyberspace will reach its vaunted potential as a useful, immersive virtual reality. Cyberspace is meant to be nothing less than the human-computer interface of the future.

But what should it look like once we've engineered the capacity to create it? Gibson's vision is rather limited here. Lines of light and glowing blue pyramids provide nice imagery for a science fiction novel, but what we require is a highly functional and truly powerful design for this new user interface. It is well established that the main conduit of information from the senses to the human brain is through vision. Thus we are going to need a carefully engineered and well-justified visual manifestation of cyberspace to fully tap its potential to organize and convey the information it embodies.

Navigation of the representation is a key issue. Early experience with virtual reality indicates that navigation of synthetic 3D spaces is difficult for humans. Keeping track of your orientation and relative and absolute positions in the synthetic environment are notoriously difficult, perhaps because of the alien appearance of the environment, its simplicity (read: lack of visual cues) compared to reality, and/or the limited engagement of our senses in current VR technology. Or perhaps it is because we, as biological entities, are better designed to deal with the kind of environment in which we evolved than with abstract, synthetic spaces.

CLAIMS

We have a biological heritage: primates roaming forests and the savanna. Invoking the neural net model, our "wetware" may be inherently optimized for certain image recognition tasks. Primary among these is apprehending nonverbal communication of other individuals of our species: we feature exquisite sensitivity to the nuances of people's facial appearances and the dynamics thereof. External to our troop of primates, we are engineered by evolution to deal effectively with features of our natural environment: terrain and other natural phenomena.

So what is the best visual manifestation of cyberspace? It should be familiar and suited to the hardwired specializations of our neural net. That is, it should appear like nature as our ancestors over the eons knew it, which was far more intimately than modern humans.

What are the fundamental features of this "natural" cyberspace? Of course, there are the standard features of a landscape scene: terrain, clouds, atmospheric effects, water, and so on. Realism in these has been, and will continue to be, addressed to ever greater satisfaction in the literature of computer graphics research. Those are the obvious phenomena. I wish to point out some more subtle, yet equally essential, requisite features of a "natural" cyberspace:

1. It should be locally two-dimensional, like the surface of the earth.
2. On intermediate scales it should be spherical, like a planet.
3. On the largest scale it should be three-dimensional, like the universe we inhabit.
4. The geometry used for its representation should be, for the most part, fractal.

Let me now motivate and justify these claims.

The locally planar appearance of our planet is compelling enough that the "flat earth" model held sway as a sufficient model of Earth quite recently in our cultural history. Furthermore, we primates generally enjoy mobility only in two-and-one-half dimensional space, that is, within a slab extending about three meters above the surface of the earth (with occasional forays into trees, multistory buildings, and such). Also, which way is "up" is rarely in doubt. These factors greatly simplify our navigational challenges. Experience with the Bryce synthetic landscape generation software product indicates that naive users find Bryce much easier to learn and operate than general 3D graphics applications. We conjecture that this may be because (1) the user is generally dealing with a 2½D space rather than full 3D, and (2) the default natural environment features a horizon and gradated-by-altitude sky, which make it obvious which way is "up." Given this familiar and nonthreatening initial environment, a new user with no prior experience in 3D graphics naturally makes straightforward progress in learning the more recondite aspects of general 3D graphics without even being aware of how difficult mastering them can be.

Simply stated, $2\frac{1}{2}$D environments appear to be natural and intuitive for the average person.

The global context for landscapes is a planet: a sphere, a globe. This alone could justify the claim that "natural" cyberspace should be spherical at intermediate scales. But there is another advantage to this geometry: it is topologically convenient. A spherical surface is finite but unbounded. This means that we can have our locally planar geometry, without worrying about falling off the edge of our necessarily finite world. It can also be a convenient boundary condition assumption for simulations such as artificial ecosystems. Finally, it can obviate, through spatial disconnection, the problem of engineering transitions between disparate models. Thus, for instance, no one would need to labor over making a seamless transition between the stylized appearance of an environment designed for interactive shoot-'em-up game play and that of an environment designed to host a set of non-real-time, scientifically accurate simulations of natural processes.

Planets, in turn, reside in the familiar context of three-dimensional space. Using three dimensions yields the maximum usable space by employing the highest usable dimension—human intuition being ill equipped to deal with higher-dimensional spaces. Three-dimensional space is obviously the way to organize our layout on the largest scale not only because it maximizes the total usable space but also because it can vastly increase the local density of information (this being only occasionally a virtue). Maintaining the argument that nature's appearance will always be the most comfortable, familiar, and efficacious of our visual options, the obvious way to lay out our universe of planets is to imitate the universe as we know it: planets reside in solar systems, solar systems in galaxies, galaxies in clusters, and clusters in superclusters. The real universe is inhomogeneous on large scales: there are vast voids between concentrations of galaxies. This, fortunately, can correspond to the good practice in visual design of judicious use of empty space (so-called negative space) to reduce clutter and guide the viewer's attention. That is, the sheets-and-voids distribution that characterizes the largest-scale structure of matter in the visible universe just might lend itself naturally to good visual design and effective imposition of (more or less arbitrary) order on the vast quantities of data that cyberspace is designed to represent for human consumption.

THE FRACTAL GEOMETRY OF CYBERSPACE

We must choose a geometry to use in constructing the visual representation of cyberspace. We have two realistic choices: Euclidean or fractal. The passage where Gibson defined "cyberspace" evokes a primarily Euclidean visualization: "lines of light . . . like city lights, receding . . ." Auspiciously, he also mentions "clusters and constellations of data," evoking the fractal geometry that generally better characterizes the forms found in nature. We're all familiar with the shapes of Euclidean geometry: lines, planes, spheres, cubes, cones, and so on. Euclidean geometry is excellent for describing things made by humans and generally poor for describing the complex forms common in nature. The opposite is true of fractal geometry. You might conclude that, since cyberspace and everything in it is a human-made artifact, Euclidean geometry is the obvious choice for its visual representation. This is probably so, *for the artifacts representing the information content* in cyberspace. That is, there will be cities and schematics of devices and text and such on the planets that comprise cyberspace; these should be represented in the familiar Euclidean way. What is better made fractal is the visual *context* for that content. I maintain that the context should be like nature, and nature is largely fractal. Yet it's not that simple and clear-cut, either.

I assume that you are familiar with Euclidean geometry; let me now give a brief overview of fractal geometry. Random fractals or so-called scaling noises such as fractional Brownian motion (Peitgen and Saupe 1988) characterize many structures in nature. Deterministic fractals such as the famous Mandelbrot set, or M-set, and the von Koch snowflake constitute another class of fractals. (Interestingly, certain deterministic fractals such as the von Koch snowflake and the Peano curve (Mandelbrot 1982) are even locally Euclidean, e.g., are comprised of straight line segments.) Fractal geometry can be most succinctly characterized as *dilation symmetry,* or invariance (perhaps only statistical) over changes in scale. That is, zooming in and zooming out, you see pretty much the same thing at different scales; appearance remains similar, hence the term *self-similarity* is used to characterize fractals. Fractal objects appear complex, due to the amount of detail evoked by this repetition of form over a range of scales. This apparent complexity may be deceivingly simple, however, as both the basic form and the rules of repetition may be very simple. How, then, do fractals mix with generally simpler Euclidean forms in our synthetic universe?

We primates are social beasts, and there will inevitably arise cyberManhattans: "hot properties," local spots where "everyone will want to be" in the vast cyberuniverse. Again, to maintain the analogy with real cities, we will probably construct them using Euclidean geometry. Yet despite its complexity and the fact that it is not generally a good language for human-made form, fractal geometry has applications in constructing cybercities: as in real cities, space in cybercities will be at a premium. Just because your company grew from two employees to owning Microsoft doesn't mean you can necessarily expand your corporate headquarters in cyberSeattle to occupy half of downtown—that space will already be occupied. But scale is an entirely arbitrary concept in cyberspace; there is no standard meter, no inherent size to anything. Thus it won't matter how "large" you loom in cyberspace, but rather how much information you have that people want to access. Using a fractal representation, you can grow "inward" by adding ever more detail that can be seen by zooming farther in to your cyberconstruct. Growing inward like this will obviate the need to occupy ever more space, to expand your hegemony by conquest or cyberimperialism. The ability to grow inward may spawn a new esthetic based—in the fine artistic tradition of contradicting contemporary values—on the idea that smaller is better, that getting the most content into the smallest space is a greater accomplishment than growing to be as large as possible. The ability to grow inward, fractally, obviates the problem of available space in our cybercities.

Two other issues indicate the use of fractal geometry in the construction of cyberspace: first, the transfer and, second, the realistic rendering of highly complex scenes. The problem of *aliasing* is too recondite to address here, but let us say that one of the main problems in rendering very complex scenes arises from the difficulties in cramming more information in the pixel grid, or *raster,* that comprises the image, than that grid can accurately represent. The problem is inevitable because of the complexity of cyberspace. Aliasing shows up as highly unnatural and objectionable artifacts in still images and worse artifacts still in moving images. Fortunately, due to their constructive or "procedural" nature, fractals can be adaptively bandlimited for alias-free rendering. That is, their construction can limit their detail to that which the raster can accurately represent. Furthermore, their procedural character ensures that everyone can explore the same synthetic universe of unlimited visual richness, without the need for hypernet bandwidth or huge, mirrored database servers simply to dish up the visual representation—as opposed to the information content—of that universe. This is because the visual richness of fractal models is an emergent property of their computation. As we have seen, a relatively simple model and a small, in terms of data transfer, number of parameter values are sufficient to generate an entire world, with potentially unlimited detail. (MojoWorld files tend to be less than 100 kilobytes in size.) A beauty of the fractal representation is that the model is tiny in comparison to the visual result. The model consists only of the basic shape and the rules for its repetition; all details emerge from the computation. This solves the bandwidth problem inherent in transferring from remote repositories to users complex representations of cyberspace—the *place,* as opposed to the *content* or information accessed there—leaving the network bandwidth free for transferring that content, which is what we'll go into cyberspace for in the first place.

CONCLUSION

In conclusion, I'd like to reiterate that the natural, fractal universe I am advocating is not an end in itself, but rather a *context* for the information content that cyberspace is designed to make accessible to humans. Cyberspace is strictly for human consumption. The machines do not need it; they do very well with their streams of binary code. Cyberspace is a visualization tool designed to make the exponentially growing stores of information entrusted to the computers, and their inherent value, available to humans who generally do poorly at comprehending binary-encoded information.

The "natural" cyberspace I am proposing is an efficacious setting for entertainment, like games and Myst-style puzzles, for synthetic ecosystems, simulated cities and civilizations, artistic creations, meditative spaces, and raw data retrieval. The suggested hierarchy going from 3D to 2½D to 2D preserves advantages of the evolved human faculties for interaction with our environment. Extensive use of fractals imparts visual richness, compact representation, and a natural visual character also suited to our naturally evolved faculties. It is familiar and expandable. It is as politically and aesthetically neutral and noncontroversial as such an important and soon-to-be ubiquitous aspect of human life can be made. Most importantly, it has the potential to be made as beautiful as the universe we inhabit, as Figure 21.1 illustrates.

FIGURE 21.1 *Dale Beach* is a visualization of what cyberspace—or at least one tiny part of it—may look like, once we have the capability of rendering it in real time. It will, of course, have representations of the data and avatars we go there to interact with, making it in essence the ultimate human-computer interface. Copyright © F. Kenton Musgrave; world by Armands Auseklis