CYBERSPACE

FIRST STEPS

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7 Cyberspace: Some Proposals

Michael Benedikt

Introduction

On the Structure and Purpose of This Chapter, with Some Prefatory Comments

After this introduction, the chapter will be in two parts. The first attempts a broad analysis of what can be said in principle about the nature of physical space—the space of the everyday world—in relation to what can be said about the nature of the artificial or illusory space(s) of computer-sustained *virtual worlds*. Because virtual worlds—of which *cyberspace* will be one—are not real in the material sense, many of the axioms of topology and geometry so compellingly observed to be an integral part of nature can there be violated or re-invented, as can many of the laws of physics. A central preoccupation of this essay will be the sorting out of which axioms and laws of nature ought to be retained in cyberspace, on the grounds that humans have successfully evolved on a planet where these are fixed and conditioning of all phenomena (including human intelligence), and which axioms and laws can be adjusted or jettisoned for the sake of empowerment. Before dedicating significant resources to creating cyberspace, however, we should want to know how might it look, how might we get around in it, and, most importantly, what might we usefully *do* there. Thus the second part of the chapter presents some visualizations and descriptions of cyberspace(s) envisaged by myself and my students over the last few years. These are put forward as imaginative proposals, as designs, as descriptions of systems almost within our technological grasp.

The tenor of the chapter also changes between the two parts. The first, in laying some of the foundations for the second, attempts to be general, closely reasoned, and philosophical in tone. Although no less fully considered, the second is laced with fine-grained aesthetic and intuitive choices for which no rigorous explanations are offered. This is due not only to the intrinsic, technical complexity and scope of the problem, but also to the multiplicity of imaginative opportunities the very notion of cyberspace affords, demanding countless intuitive leaps and best guesses—fixings upon what simply seems good, workable, or interesting—from all who would enter into the task of its design.

Throughout, I write as a designer and theorist trained in architecture, and not as a computer scientist, mathematician, sociologist, or artist. In these fields I have only a modicum of specialized knowledge. Thus, my discussion will (try to) avoid the use of standard jargons from these areas of knowledge, as well as from my own field, architecture.

Some Remarks about Content

Time and Cosmology In Part One I will attempt to define ordinary, physical space in a useful way. In the process I will need to recall and examine many truisms from modern science and mathematics. The exercise is worthwhile precisely because we are contemplating the design and implementation of an experienceable (actual) but nonphysical (unreal) space such as cyberspace. Since in cyberspace the very concept of *space* is clearly at issue, is not the concept of *time* also at issue? How should time be treated?

In both parts of this chapter, time is considered as a distinct and nonspatial dimension: "nonspatial" even though, as is well known, the dimension of time in such phenomena as physical motion and the transmission of energy and information is intimately involved with the dimensions of space.[1] Thus the reader will find very little talk of the "proper" unity of space and time associated with Minkowskian space-time, and only tangential discussion of relativity, cosmology, and quantum mechanics, where the dimension of time is often treated as all but interchangeable with spatial and other fundamental dimensions of reality. This is not because there is nothing "cosmological" to discuss in designing and modeling cyberspace. Far from it! Dwelling on the notion of cyberspace fairly *demands* that we query why things are the way they are in nature, and I find it necessary to speculate on cosmological matters more than once. However, as plausible and informed as these speculations may or may not seem, they are not put forward as serious and rigorous proposals about the nature of the real physical world. They are presented, rather, as comparative notes, as meditations on the way to a rich, viable, consensual, and "virtual" parallel one.

Why Cyberspace? The reader will not find much discussion as to *why* we need to have cyberspace(s) at all. This very worthwhile debate must take place elsewhere. Here, almost by way of manifesto, it must suffice to say this:

Over the last twenty years the economies of advanced industrial societies have evolved rapidly. Though still founded on agriculture, manufacture, transportation, and energy production, a steadily larger portion of human activity has become increasingly involved with, and transformed by, the production and consumption of *information* as such—with finance, communication, advertising, education, entertainment, management, and the control and monitoring of complex natural and industrial processes. As a result, the economic principles of material production and distribution in their classically understood forms—principles of property, wealth, markets, capital, and labor—are no longer sufficient to describe or guide the dynamics of our modern, complex, "information society."

On the experiential front, our lives are changing too. Ever more dependent upon channels of communication, ever more saturated by the media, ever more reliant on the vast traffic in invisible data and ever more connected to the computers that manage it, we are becoming each day divided more starkly into the entertainers and the entertained, the informationally adept and the informationally inept. Bombarded everywhere by images of opportunity and escape, the very circumstances of a free and meaningful human life have become kaleidoscopic, vertiginous. Under these conditions, the definition of reality itself has become uncertain.[2] New forms of literacy and new means of orientation are called for.

Thus it is proposed that the creation of cyberspace is not only a good, but necessary, and even inevitable step (1) toward providing the maximum number of individuals with the means of creativity, productivity, and control over the shapes of their lives within the new information and media environment, and (2) toward isolating and clarifying, by sheer contrast, the value of *un*mediated realities—such as the natural and built environment, and such as the human body—as the source of older truths, silence of a sort, and perhaps sanity.

What Is Cyberspace? A Preview

I will attempt to provide a preliminary sketch of cyberspace. But first, this question: How does "cyberspace" relate to "virtual reality (VR)," "data visualization," "graphic user interfaces (GUIs)," "networks," "multimedia," "hypergraphics," and other such catchwords for recent developments in computing technology?

The answer: Cyberspace relates to all of them. More than this, in some sense "cyberspace" *includes* them all and much of the work being done under their rubrics. Indeed, I would assert that cyberspace as a *project* and as a *concept* has the capacity to collect these disparate projects into one—to focus them on a common target, as it were.

That said, my efforts here will likely fall short of providing a picture of that target that is clear and useful for all. And that is as it should be. For it is too soon for anyone to specify very fully the nature and uses of cyberspace. Just as there will likely be myriad places *in*, and many regions *of* cyberspace—each with its own character, rules, and function—in due time there may also be a number of different kinds of cyberspaces, each with its own overall culture, appearance, lore, and law. Someday, these cyberspaces and cyberspatial "domains" may well compete with each other just as information services and telephone companies do now. Some will thrive and some will not. Today, however, the very process of fairly specifically visualizing and describing models of cyberspace will help clarify the issues for all.

The enormity of the evolutionary step represented by cyberspace will claim our attention repeatedly. But what *is* cyberspace? I have assumed that the reader of this volume already has some familiarity with the term, but, for the purposes of this essay, and so that we can proceed with some clearer and common picture in mind, I offer this general description (written, somewhat prematurely, in the present tense):

Cyberspace is a globally networked, computer-sustained, computer-accessed, and computer-generated, multidimensional, artificial, or "virtual" reality. In this reality, to which every computer is a window, seen or heard objects are neither physical nor, necessarily, representations of physical objects but are, rather, in form, character and action, made up of data, of pure information. This information derives in part from the operations of the natural, physical world, but for the most part it derives from the immense traffic of information that constitute human enterprise in science, art, business, and culture.

The dimensions, axes, and coordinates of cyberspace are thus not necessarily the familiar ones of our natural, gravitational environment: though mirroring our expectations of natural spaces and places, they have dimensions impressed with informational value appropriate for optimal orientation and navigation in the data accessed.

In cyberspace, information-intensive institutions and businesses have a form, identity, and working reality—in a word and quite literally, an *architecture*—that is counterpart and different to the form, identity, and working reality they have in the physical world. The ordinary physical reality of these institutions, businesses, etc., are seen as surface phenomena, as husks, their true energy coursing in architectures unseen except in cyberspace.

So too with individuals. Egos and multiple egos, roles and functions, have a new existence in cyberspace. Here no individual is appreciated by virtue only, if at all, of their physical appearance, location, or circumstances. New, liquid, and multiple associations between people are possible, for both economic and noneconomic reasons, and new modes and levels of truly interpersonal communication come into being.

Cyberspace has a geography, a physics, a nature, and a rule of human law. In cyberspace the common man and the information worker—cowboy or infocrat—can search, manipulate, create or control information directly; he can be entertained or trained, seek solitude or company, win or lose power . . . indeed, can "live" or "die" as he will.

Now this fully developed kind of cyberspace does not yet exist outside of science fiction and the imagination of a few thousand people.[3] However, with the multiple efforts the computer industry is making toward developing and accessing three-dimensionalized data, effecting real-time animation, implementing ISDN and enhancing other electronic information networks, providing scientific visualizations of dynamic systems, developing multimedia software, devising virtual reality (VR) interface systems, and linking to digital interactive television . . . from all of these efforts one might cogently argue that cyberspace is "now under construction." Even popular computing's fascination with "windows" and 2+ dimensional graphic user interfaces (GUIs), together with the nation's burgeoning on-line newsgroups, electronic communities, and hacker subcultures can be seen as moves, however unwitting, towards the creation, someday, of the full-blown, public, consensual virtual reality that will indeed be *cyberspace*.

On the largest view, the advent of cyberspace is apt to be seen in two ways, each of which can be regretted or welcomed: either as a new stage in the *etherealization* of the world we live in, the real world of people and things and places, or, conversely, as a new stage in the *concretization* of the world we dream and think in, the world of abstractions, memory, and knowledge.

Both views are useful. But both are misleading insofar as they are both implicitly modeled on the historical processes of transformation, usurpation, and replacement rather than those of evolution, speciation, and displacement. With cyberspace the real world (let us grant some consensus here as to its physicality) does not *become* etherealized and thus, in the aggregate, less large or less real; nor does the "mental" world *become* concrete and thus, itself, less mental or spiritual. Rather, with cyberspace, a whole new space is opened up by the very complexity of life on earth: a new niche for a realm that lies between the two worlds. Cyberspace becomes another venue for consciousness itself. And this emergence, proliferation, and complexification of consciousness must surely be this universe's project.

Akin to the Teilhardian "noosphere," then, but not in any sense ideal, transcendent, or beyond reality, cyberspace unfolds in an expanding new landscape of ideational and electronic complexity.[4] But, just as printing did not *re*place but *dis*placed writing, and writing did not *re*place but *dis*placed storytelling, and just as movies did not *re*place theater, nor television movies . . . cyberspace will not replace either objective reality or dreaming and thinking in their historical modes. Cyberspace will not replace art museums, concerts, parks, or sidewalk jugglers; nor sex, books, buildings, or radio. Each of these earlier media and activities will move over a little, as it were, free—indeed obliged—to become more themselves, more involved in their own artistry and usefulness. Each will be dislocated in certain dimensions but freed in others, as Innis, McLuhan, and Carpenter so clearly saw.

Part One: On the Nature of Space, and Cyberspace

What Is Space?

We must begin with a large question: What is space? The existence and nature of space seems to be a truly basic, fundamental, and universal quality of reality; and if not of reality proper and entire, then, as Kant propounded, a necessary feature of our mind's operation in relation to it, and within it. Space and time, combined, appear to constitute a level of reality below which no more fundamental layers can be discerned, a field without natural parts, a universal attribute of Being that cannot be done away with, as much as Hume tried to do so.

As a rule we do not expect clear and final answers to metaphysical questions such as the above, questions among which we must include "what is the essence, or origin, of *space*?" Cast them as practical and empirical questions about physical reality, however, and we do expect some clear and helpful, if not final, answers from science. Can science, and especially physics, help us answer the question "What is space?" Is space a physical phenomenon, an *object* in some sense?

Insubstantial and invisible, space is yet somehow *there*, and *here*, penetrating, and all around us. Space, for most of us, hovers between ordinary, physical existence and something other. Thus it alternates in our minds between the analyzable and the absolutely given.

Or so it was until modern physics and mathematics revealed space's anatomy, as it were, showing its inextricability from the sinews of time and light, from the stresses of mass and gravity, and from the nature of knowing itself. The early part of the twentieth century saw post-Euclidean geometry and the Theory of General Relativity admit the concepts of curvature and higher dimensions, introducing "inertial frames," "manifolds," "local coordinate systems," and "space-time" to all informed discourse about space. These ideas had myriad practical consequences. Physical space, we learned, is not passive but dynamic, not simple but complex, not empty but full. Geometry was once again the most fundamental science.

With the techniques of differential geometry and algebraic topology we have come far in our power to reason mathematically about space's structure and "behavior." But our understanding of physical space's *actual* dimensionality, size, curvature, and grain at the macro- and microscales is less advanced, just as it is of physical space's relationship to the "mental spaces" of logic, representation, and the free imagination. Further, our understanding of the connections to the space and time of everyday experience—from mathematics and physics, through biological and social structures—has not improved very much in centuries. So if we can form neither a secure picture of physical space or space-time at the extremes of scale and velocity, nor a new picture of space in the ordinary sense, how can we intelligently, freshly, preferably scientifically, and with a view to creating cyberspace, answer our question "What is space?" Must we draw a blank?

Not entirely. We can define "space" in phenomenological, operational terms. That is to say, we can talk about how space appears/feels to us, and what both space and various concepts of space are "good for" objectively. We can ask: What operations does space permit or deny? What phenomena would be different if space were not "constructed" in this way or that? In what elusive physics are we so embedded that we cannot report on its laws? And if physical space *has* a discoverable and constrained topology, what of spaces of the imagination? Is not our ability to construe the latter precisely that which throws the former into relief?

With cyberspace, we ought not to feel dissatisfied to begin with a phenomenological/operational method, this rather than seeking after the objective *facts* of nature's infinitely subtle spatiotemporal constructions in the laboratory. Phenomenology, after all, entails nothing less than *taking appearances seriously*, and, containing no material objects, no energics, no physical dynamics, cyberspace is just such a realm of appearances to be taken seriously. Furthermore, cyberspace's spatiotemporal logic need only be consistent internally and locally. We do not presume to construct a permanent universe. Thus the criteria for success are pragmatic and human from the outset—workability, pleasure, and human empowerment taking precedence, always, over utter fidelity to nature at large.

Space as Freedom of Movement

Here is one phenomenological approach to a definition of space.

In almost all instances, and perhaps most irreducibly, space presents itself to us in the *freedom to move*, a freedom we "know" from the moment of birth.[5] Later in life—and in distinct stages, as Piaget showed—we come to reflect upon how the very possibility of movement depends on the preexistence of different and discrete locations for the same thing (including our bodies), locations between which continuous movement—that is, movement through all intervening locations—must occur over time.

So far so good. But notice: if the above is to function as a definition of space, a whole set of codependent terms must be grasped all at once: "location," "continuity," "identity," "freedom," "change" (and therefore, implicitly, time), terms which, alas, require that we already have some understanding of "space"!

Luckily, as evolved creatures, we have considerable knowledge of space "hard-wired" into each of us. This knowledge exists not just insofar as the laws of physics and chemistry "require" of all real things—brains no less than stones—that they be *in* and *of* space and time, but also as the set of everyday bodily sensations, reactions, and expectations, which appear to us as having immediately to do with the world's spatiotemporality.

For example, we simply *find* that can see and imagine innumerable discrete locations existing simultaneously: things in other places. With our eyes, and in our mind's eye, we can see innumerable paths and routes between locations; we see that most objects retain their *identity* as they move from one place to another. The phrase "the shortest distance between two points" immediately suggests "a straight line" to us, and we can easily extend this notion to the idea of a shortest time between two points, which may, or may not, be a straight line. We observe that objects do not really disappear here and reappear there in a disjointed or instantaneous fashion, though they may sometimes appear to, but must instead travel *between* here and there continuously, even if the route is concealed or very swiftly taken. Finally, we begin to assume that this arena of compounded, possible positions and reversible movements extends smoothly and indefinitely beyond our immediate perception in every "direction" (which is another whole story), retaining its local characteristics. This large set of phenomena, with its logical bounds and experienced character, we call *space*.

We must be clear about what is achieved when we "define" terms operationally and phenomenologically as we just have, especially when the definition seems causally or logically to antecede the defined. Defining A as "that which permits B, C, D . . . " (as in "space is that which permits identity, movement, size, etc.") is not a discovery of essences or of necessary grounds but a directive to examine carefully and critically the most immediate conditions, consequences, properties, and manifestations—*signs*, if you will—of a unitary A whose actual existence is, at best, sensed and presumed rather than seen and known directly.

The codification of such signs into a minimal and yet complete set often constitutes a set of *principles*, taken as necessary and sufficient conditions for, or "attributes" of, A. We will be looking at some of these shortly.[6]

We may need to employ advanced mathematical techniques in the design and operation of cyberspace. However, as esoteric as our thinking may become (and this quite aside from esoteric technical knowledge of hardware and software) we will have to ensure—in best computer industry tradition—that the ordinary user comes first. Even as we strive for higher dimensionalities or supernormal capabilities for the denizens of cyberspace, ordinary space and time must form the basis, the norm, *any departures from which* we must justify. Neither an advanced degree in math nor extraordinary powers of visualization ought to be necessary for a reasonably well-educated person to spend time productively in cyberspace.

Magic in Cyberspace: The Violation of Principles

As we know and will soon examine, in patently unreal and artificial realities such as cyberspace, the principles of ordinary space and time, can, in principle(!), be violated with impunity. After all, the ancient worlds of magic, myth, and legend to which cyberspace is heir, as well as the modern worlds of fantasy fiction, movies, and cartoons, are replete with violations of the logic of everyday space and time: disappearances, underworlds, phantoms, warp speed travel, mirrors and doors to alternate worlds, zero gravity, flattenings and reconstitutions, wormholes, scale inversions, and so on. And after all, why have cyberspace if we cannot (apparently) bend nature's rules there?[7]

But let us notice two things: first, that there is a limit to how frequent and severe such transgressions can become before credibility, orientation, and narrative power begin to be lost; and second, that myth and fiction do not contain violations of ordinary spatiotemporal logic but *descriptions* of such violations. Only today, and only on the display screen of a computer, can we find even modest spatiotemporal "miracles" actually performed in real time, routinely, and under our individual control.[8] One has only to watch an expert handling contemporary graphic user interfaces: exploding and collapsing icons; slip-sliding, disappearing, and reappearing panels and windows lapping each other six "deep"; buttons and sliders that are neither buttons nor sliders, that don't care where they are, and yet work; cursors that change what they are and do, depending on where they are; the stripping, skipping, scrolling, flying, popping, and gobbling . . . "effects," all, which are critically effective and have real world consequences, and yet when understood physically, at the level of the phenomenon, would call for a major rewriting of the laws of physics.[9] Similarly, the kinds of action "possible" within the fictional worlds of computer interactive fiction, video games, and consensual, real-time, nationally networked adventure worlds such as Habitat and Club Caribe, Carnegie Mellon's marvelous TinyMUD, and the latter's current spin-offs, defy physical constraints routinely. Magic!

In a way, cyberspace *is* the future of both graphical user interfaces (GUIs) and of networked text-games based on the place metaphor such as TinyMUD (more about this later). For cyberspace will not be just a description or staging of an uncanny reality—a matter of mental effect as in a novel, play, movie, or video game. More like GUIs, it will institute a virtual reality as a functional, objective component of physical reality. Cyberspace will provide a three-dimensional field of action and interaction: with recorded and live data, with machines, sensors, and with other people. Beyond consequences in cyberspace, these interactions will also have consequences that reach directly back into the physical world, from the efficient running of corporations, governments, and small businesses, to the enrichment of our individual lives with entertainment and communication . . . in short, to our real health, wealth, and happiness. After all, "cyber" is from the Greek word *kybernan*, meaning to steer or control.

What about interfaces beyond GUIs? With such new devices as data gloves, data suits, and head-mounted stereographic displays, a three-dimensional, electronically construed space may be entered sensorially. Is this vanished "interface," this envelopment by a computer-generated world already cyberspace? That is, *is the kind of experience afforded by virtual reality technology, ipso facto, cyberspace?* The answer has to be yes, and no.

The Independent Existence of Virtual Worlds

Cyberspace must be envisaged as a coherent and global virtual world independent of how it is accessed and navigated. There may be not one, but many ways to enter cyberspace, from simple, mouse-controlled animation of video monitor images, through VR (virtual reality technology being directed at re-creating the human sensorium as fully as possible), to direct neural plugs (as William Gibson imagined). Once in cyberspace, there may be many ways of getting around, from walking and crawling, to leaping through worm holes, from "bareback" riding or cyberBuick cruising, to floating and flying unencumbered. And there may be just as many alternative modes of action and manipulation. In other words, like a city, cyberspace is there to contain all these activities, happen as they may.[10] Therefore, although it depends on them technically, cyberspace itself is neither a hardware system, nor a simulation or sensorium production system, nor a software graphics program or "application." It is a place, and a mode of being.

These observations have immediate implications. For one, they help us see that the design and development of computer-human "interfaces," although a crucial and interesting complementary enterprise, is a separate project from the design and development of virtual or artificial worlds with which one would want to "interface" in the first place, regardless of how advanced the technology of "virtuality," of sensorium synthesis.

To illustrate the difference: few designers of today's GUIs, few journalists who observe today's GUI wars, and few GUI users are aware that two, separable systems are being created simultaneously: one is the space of window manager (WM) itself, and the other is the set of spaces in which both the WM and the data cooperate, spaces that can have their *own* value-laden lefts/rights, ups/downs, ins/outs, objects/voids. And of course, the two systems—the WM space and the data space—need not operate in lockstep. To make matters worse, they can be nested in each other indefinitely. For example, one will be as likely to find GUIs in cyberspace as cyberspace in GUIs.

Here is a simple example of the hidden valences of the WM space of a "desktop" GUI: why is the Macintosh trashcan icon—pale and ashen—positioned at the bottom right of the screen, while the rainbow-colored apple icon of the Apple system menu—happy and edenic—is positioned diametrically opposite, at the top left? Why have almost all GUI designers agreed that the top of the screen is icon/menu territory? These are vestiges of the organization of *pages*, which for thousands of years (even before there were "pages") have given different value to the top and bottom, center and margin, left and right, of things in general and then to fields of inscribed, textual and graphic information.[11] And whence *these* value assignments? From the body—with its eyes and anus, skin and heart—and from the earth, with its life, light, and view above and over, and its inert, dark, and blind things below and under. However subtle, these kinds of spatial/positional values will persist in the three dimensions of cyberspace.

But I am getting beyond the question. The point here is that the natural spatiotemporal principles suitably instated in the design of a vehicle/window manager need not be the same ones that govern the behavior of objects in the space of cyberspace itself, neither alongside the vehicle/window manager nor, further, inside/beyond each window. "Laws of physics" can apply differently to different classes of screen objects: this is already the case in all contemporary GUIs (though the Apple Macintosh's comes to mind most strongly here).

The ultimate *physical* basis for cyberspace resides, of course, in the actual construction and architecture of computers and communication links: in chips, circuits, crystals, cables, etc. Here, in the orchestrated flow of the myriad electrons and photons we expect no space-time miracles, no uncanniness. But cyberspace as such exists at a higher level evolutionarily and phenomenologically, that is, at the level of human perception and experience, thought and art. And it is at this higher level that the question of its "laws" comes into play. In cyberspace, I am saying, the distinctions that are already a part of GUI and game design will become keener, the number of permutations larger, and the necessity for a "natural order" and a consensus even greater.

In sum, then, it would be unwise to ignore the design of cyberspace itself while we are engaged in the myriad considerations of particular GUI and VR implementations. The design of cyberspace is, after all, the design of a another life-world, a parallel universe, offering the intoxicating prospect of actually fulfilling—with a technology very nearly achieved—a dream thousands of years old: the dream of transcending the physical world, fully alive, at will, to dwell in some Beyond—to be empowered or enlightened there, alone or with others, and to return.[12]

The Principles of Space and Cyberspace

Like the real world, cyberspace will continue to enlarge, to fill in, "complexify," evolve, and *in*volve, indefinitely. In time, the detailed and perhaps painful reexamination of the constraints, laws, and opportunities of the natural and physical life-world necessarily undertaken by cyberspace's first designers will become less frequent and less necessary. The second generation of builders will find that the new reality has its own, seemingly self-evident, rules.

Having gained some impression of what I mean by "cyberspace," we now turn to the task of considering its possible rules and principles. Using decidedly low-altitude mathematics, we will look at these in relation to the rules and principles of natural, physical space, and under five, essentially topological rubrics: *dimensionality, continuity, curvature, density*, and *limits*.

From this will emerge seven principles:

the *Principle of Exclusion* (PE)

the *Principle of Maximal Exclusion* (PME)

the *Principle of Indifference* (PI)

the *Principle of Scale* (PS)

the *Principle of Transit* (PT)

the *Principle of Personal Visibility* (PPV)

the *Principle of Commonality* (PC).

Each principle identifies a critical juncture in the system of possible correlations between the behaviors of physical space and cyberspace. These seven are neither empirically observed, as are the consequences of the various laws of physics, nor merely invented, as are those of the "laws" of fantasy worlds. Neither cast in stone nor wholly contrived, these principles, I will try to argue, are at the very least felicitous *conventions* for cyberspace, derived from the constraints and opportunities that physical reality seems to have chosen for itself, as well as the inherent limitations of computing and electronic communications. The models of cyberspace presented in the second part of this chapter are derived from, and are consistent with, all seven principles.

Dimensionality

We speak easily of physical space being three-dimensional. (As I mentioned earlier, I will treat time conventionally.)[13] But what is a *dimension* in our context? And what does it mean to say that space "has" three of them?

Though I will approach the problem as directly as possible, I must begin with a simpleton's view of the matter and hope that the reader will be patient when he encounters what is, to him, well understood. I will also answer the question backwards, beginning with consideration of abstract, numerical spaces (to which cyberspace is related) before coming back to real space.

Let us assume that we have before us some physical system, object, or phenomenon, dwelling and acting in ordinary space and time, such as an ecological system, a power plant, or any complex machine. We wish to *describe* and represent the system, and thus come to understand how it behaves and how we might control it. We might make some kind of measurements of the system's behavior through time; in fact, we would make a set of N different kinds of measurements, each of one aspect of its behavior. If these measurements are quantitative at all (if they have a largely numerical basis as in reading the control room's dials and gauges) or have any sensible linear ordering, then we can speak of the *state* of the system at a time *t* as the instantaneous value of all the measured variables, taken as a set, at time *t*. The behavior of the system is therefore reasonably described by the entire time-ordered set of states. Indeed, for some purposes, the system may be thereby defined.

Visualization If we are fortunate enough to need only two variables to describe the system's behavior then we can visualize the system's behavior in toto by plotting the two variables "against" each other on a chart. Each variable becomes one (pseudo)spatial *dimension*, which is commonly represented by one axis of a rectangular coordinate system laid out on a piece of paper, chalkboard, or computer screen. A *point* in this plane—in this space defined by the coordinate system—can therefore represent a certain state consisting, by definition, of the simultaneous, specific values of two variables. A continuous curve in this space can record the way these two variables covary smoothly in time—the system's "behavior"—or it can describe all the realizable states of the system, or both. A scattering of points has its own meaning too. It may represents some discontinuity of system behavior, or the action of a hidden, orthogonal variable such that the scattering of points manifests the peaks of a "submerged" surface, like island archipelagos.

A point in a three-dimensional coordinate system represents a single three-variable state, a curve a contiguous set of three-variable states, and so on. We may find—as we plot the states of our system in this abstract *data space*—that certain regions are more populated with points than others, representing the set of states the system is "in" most often and/or the action of a hidden variable. Surfaces may appear in our space, as may volumes of various shape, describing/recording the limits of the behavior of the system. These in turn may change over time . . . and so on.

All this is well understood. The role of computers in visualizing system behaviors in this abstract way is also well appreciated. But what if the system under review requires that we pay attention to five or more variables? Assuming that we still wish to visualize it, we face some design decisions: most of us simply cannot directly visualize four-or-more-dimensional spaces.[14]

We might simply *decide* which dimensions to work with, and drop the others. Working in round-robin fashion, we can then produce many representations of the system, no one of which will be complete in itself. Then we can look at all of these together, assembled in some way.

Or we may choose which dimensions to assign to "coordinate duty," and which to assign to the *character* of the point in the coordinate space, so that the character of the point and its position *together* describe a state of the system. This is the strategy I want to look at more closely. In a simple version, it is a strategy adopted by a number of investigators today (see Cox 1990, Ellson 1990, Brown, De Fanti, and McCormick 1987, for examples). But because of its profound importance to the development of cyberspace, here I attempt a general formulation.

Extrinsic and Intrinsic Dimensions In Euclidean geometry, a "point" has no character: it has no size and no intrinsic, inherent properties. When one makes the statement "There *exists* a point such that . . . ," the point exists as pure position, and herein precisely lies its conceptual usefulness.[15] But in the physical world (and certainly in the world of actual representation) a point is always a "something"—a dot, a spot, a particle, or a patch of a field—a *point-object* to which one or more values can be attached that are descriptive of its character. In other words, unlike a true, Euclidean point, a point-object might have a color, a shape, a frequency of vibration, a weight, size, momentum, spin, or charge—some *intrinsic* quality or set of qualities that is logically (though it may or may not as matter of empirical fact *be*) independent of its position in space.

Now, any N-dimensional state or behavior of a system can be represented in what I would like henceforth to call a data space[16] of point-objects having **n** spatiotemporally locating, or *extrinsic* dimensions, and **m** *intrinsic* dimensions, so called because they are coded into the intrinsic character of the point-object.[17]

In sum:

$$\mathbf{N} = \mathbf{n} + \mathbf{m} \qquad (\mathbf{N} > 0\ ,\ 0 < \mathbf{n} < 5)$$

(# of) system dimensions = (# of) extrinsic dimensions + (# of) intrinsic dimensions.

Of course, if some of its assigned intrinsic dimensions are coded into perceptible, perhaps variable, size and shape, the point-object may no longer be able to be very pointlike geometrically speaking. Thus, a nontrivially sized object's so-called external dimensions, in the sense of some set of "external measurements" that depend on its shape belong, in our nomenclature, to its *intrinsic* dimensions because they belong to/characterize it as an object. By the same token, "internal dimensions," as of a room or car or pipe, are also intrinsic to the thing. In a data space, an object always contains within itself a privileged *address-point* (or, simply an *address*, given in extrinsic dimension values) that functions to identify accurately its position as a whole in the data space. Because intrinsic dimension data exist, technically, only *at* address points, an object may change its size and shape as its address changes—in other words, as it moves. Phenomenally, the moving object "taps" and reveals the data embedded in, intrinsic to, each address in the data space. One can see why *color coding* point-objects is so useful. Because (perceived) color consists in three, naturally intrinsic and non-space-occupying, orthogonal dimensions (RGB or HSV), color will not interfere when we wish to interpret the *configuration* of many closely positioned point-objects in reference solely to their positions in the data space, that is, their composite "shape."

Identity, Similarity, and Difference If the behavior of a phenomenon or system can be cast as variables or "dimensions" at all, then these dimensions can also, in principle, be partitioned into two classes, namely, extrinsic and intrinsic to point-objects in a data space, as I have outlined. Given this, some convenient definitions follow.

Any two objects in the same data space can be said to be *identical* if they have the same values on the same, matching intrinsic dimensions; *similar*, if they have different values on the same, matching intrinsic dimensions; and *different* if they do not have the same intrinsic dimensions.

If we consider any two objects, each in a different space—that is, each having different set of extrinsic dimensions—then they can be said to be *superidentical* if they have the same values on the same, matching, intrinsic dimensions, *supersimilar* if they have different values on the same, matching intrinsic dimensions, and *wholly different* if they do not have the same intrinsic dimensions. (Notice that these definitions are meaningless for true Euclidean points, since points have no intrinsic dimensions. In other words, with a parallel argument made for true points' extrinsic dimensions, two points could be identical but not superidentical.)

The case of two, nonidentical objects having the same extrinsic dimensions and dimension values, whether at the same time, or including time as an extrinsic dimension at the outset, is forbidden, no matter what other comparisons may be made between their intrinsic dimensions and values. This constitutes the *Principle of Exclusion*[18] (PE) a commonsensical though very deep principle that in ordinary language says, "You cannot have two things in the same place at the same time." The case of two identical objects sharing the same place in space and time, of course, is solipsistic, since we could only be speaking of one self-same object.

A similar set of definitions can be made for single objects or point-objects that *move* through space in time. Any single object can be said to have *self-identity* if it preserves the same values on its intrinsic dimensions as it changes one or more of its extrinsic dimensions values (moves continuously in the space), and *self-similarity*[19] if one or more of its intrinsic dimension values are operationally linked to one or more of its extrinsic dimension values. Points in a "field" with gradient $\neq 0$ are self-similar by this definition.[20] If an object either switches or changes any of its intrinsic dimensions *in kind* as it moves (and not just, or in addition to, the values of such dimensions), then we can speak of its "transformation" as its *strange identity*.

There may be situations in which we may wish to distinguish whether a point-object has *super-self-identity*, or *super-self-similarity*. If it becomes "wholly different" from itself when in different spaces, then the question of "identity" becomes spurious: after all, in what sense is it the same object? The Principle of Exclusion does not apply to single objects.

Because there is some freedom in how to choose, partition, combine, and encode **m** intrinsic and **n** extrinsic dimensions for the representation of a any N-dimensional system as a data space, the shape and behavior of objects representing the system may appear different in each choice set. Provided that no information is lost, such representations are mathematically equivalent. But they are not necessarily functionally equivalent. In other words, when searching for a useful representation of a system of any complexity, it remains an empirical question as to which visualization—which partitioning of dimensions into intrinsic and extrinsic, which scheme of creating "objects" of character and the "spaces" of their inhabitation—will create a view most immediately intelligible and/or ultimately rewarding. In this sense, there is *more* information in a "good" visualization, and less in

		Extrinsic Dimensions		
		Same dims, same v's	**Same dims, diff. v's**	**Diff. dims**
Intrinsic Dimensions	**Same dims., same v's**	*self-same*	*identical*	*super-identical*
	Same dims, diff. v's	*PE and PME excluded**	*similar*	*super-similar*
	Diff. dims	*PME excluded**	*different*	*wholly different*

(Note: "dims "= dimensions, " v's "= values, "diff" = different
* discussed below)

Figure 7.1
Summary of relations of two data objects.

a "bad" one, and one must say that all representations of the data are *not* equivalent, even when all data points are in fact somewhere represented.

Given that there can be an enormous number of ways to partition the dimensions of a multidimensional system—and quite apart from any design decisions as to orientation, scale, and what sensible qualities should manifest them—are there any heuristics rules that can make the search for the best one shorter? I think there is one very fundamental one, namely the Principle of Maximal Exclusion.

Before we move on to this principle, we should now note that although all of the discussion above has been framed and conceived in terms of data spaces, it can apply as well to properly physical spaces. After all, there is no reason why the most suitable extrinsic dimensions to use in the description of any given system should not turn out to be the familiar X, Y, Z, and T axes of physical space and time, interpreted in their most neutral, Newtonian/Cartesian fashion, and merely *pictured* in cyberspace. Similarly, the most suitable intrinsic dimensions to use in describing a physical system may well turn out be the quite familiar momentum, charge, polarization, color, etc., or the myriad statistical compoundings and derivations of these that comprise the identity and behavior of relevant, separate parts of a physical system. This conception of things is carried out frequently, in pure and hybrid forms, in the fields of scientific visualization, geographic information systems, and so on. For example, it is common for one or more axes of two- or three-dimensional diagrams to map real distance or time, while the others have purely informational value, such as a geographic map in the X-Y plane where Z-values define a data surface of "land value" in units of dollars, or a map of the sky with stars where redshift, brightness, and a host of other spectral characteristics of stars are thought of as their intrinsic dimensions. Similarly, there may be occasions on which the neutral, uncoded, and unvalenced space "made" by Newtonian/Cartesian coordinates, interpreted as real space, serve as the best setting for objects whose shape, character, and solitary behavior—that is, whose intrinsic dimensions—*alone* are left to carry the entire responsibility for representing a system's behavior. In this case, space and geometry do not matter. There is no significance to up or down, left or right, closeness or distance. Satisfying only PE (and PME), objects form simple collections.

Some speculation: what if the very existence of (physical) "space," of "time," and of (self-identical) objects "in" space and time (the very terms and structure by which, as Kant observed, we comprehend reality) represents only a special case—a subset—of all the possible partitionings of the universe's variables into extrinsic and intrinsic dimensions? Then we might ask, Why did nature choose to divide her dimensions the way she did?[21]

We cannot of course really know why or even really how, but we can discern, I believe, a principle at work which, as designers of cyberspace, we may wish to emulate: the Principle of Maximal Exclusion.

The Principle of Maximal Exclusion (PME) advises the following: *Given any N-dimensional state of a phenomenon, and all the values—actual and possible—on those N dimensions, choose as extrinsic dimensions—as "space and time"—that set of (two, or three, or four) dimensions that will minimize the number of violations of the Principle of Exclusion.*

This strategy minimizes information lost when multiple identical objects, without PME in operation, would be collapsed into single, self-identical ones, and multiple nonidentical objects would lose such self-identity as they (each) had. Let me give an example.

I have before me a two-color photograph, P. It consists of a large but finite number of point-objects {x, y} whose extrinsic dimensions—X and Y—are the width and height of the photograph, and whose intrinsic dimensions are A and B, the two colors. The phenomenal color of a point is thus given by a pair of numbers {a, b}. At every definable position on the photograph (x in X, y in Y) there exists an object of certain color (a in A, b in B).

Now, it might occur to me to make a complementary photograph, P′ of P, by exchanging the role of extrinsic and intrinsic dimensions, mapping one onto the other:

$$P = \{a, b\}_{x,y} \rightarrow \{x, y\}_{a,b} = P'.$$

That is, I make a "photograph" of dots whose extrinsic, spatial dimensions (X′ and Y′ of P′) are A and B of P, and whose color dimensions (A′ and B′ of P′) are X and Y of P. Thus the color of a dot in P determines its position in P′, and the position of a dot in P determines its color in P′.

With a little thought we can see what would happen: as it is likely that there will be many dots in P that have the same color, these dots will wind up co-occupying the same position in P'. Conversely, because in P each and every dot's extrinsic dimension values are different, in P' no two dots will have the same color. This last transformation may not be a bad thing because information is not lost, but in the first, clearly, information is lost in violating the Principle of Exclusion. In mathematical terms, we have the problem of the many-to-one mapping. Thus, given data as a set of values on four unlabeled dimensions with which to construct a two-dimensional image, the Principle of Maximal Exclusion tells us to partition the dimensions such that dimension-pairs producing the largest number of unique tuples (or two-vectors) should serve as extrinsic. Computationally, this is a simple procedure for any real data set.

The Principle of Maximal Exclusion has a corollary that one might call the Principle of Maximal Object Identity (PMOI). It says this: *Choose as **m** intrinsic (object) dimensions that subset of **n** dimensions that minimizes the occurrence of unique m-tuples.* Together with PME, PMOI, I believe, provides a powerful heuristic for visualizing data to the best advantage.

Though something of a digression, let us look at these two principles, PE and PME, a little more closely.

From Democritus to present-day quantum physicists, the whole philosophical and scientific project that goes by the name "atomism" has consisted in pursuing a double goal: (1) the preservation of PE, and (2) the reduction of the number of permissible intrinsic dimensions of the physical universe, ultimately, to one; that is, the goal of producing a viable picture of reality consisting only of irreducible objects whose only quality is existence, and which cannot occupy the same space at the same time. Disallowed is the notion that atoms can have space, can be "internally open" and indefinitely so.[22]

In ordinary life there can be rooms within rooms, to be sure, literally and metaphorically, and this "anti-atomistic" fact constitutes one of the basic techniques of data manipulation in cyberspace, as we shall see. Though it obeys PE and PME, cyberspace is not consistently atomistic. Certainly no claim is made as to the objective, physical nature of the things of interest in cyberspace, nor is any privilege claimed as to the fundamentality of such space-within-space descriptions. There is no need. In cyberspace all entities are merely data entities, pure information, from the outset, picturing for us the gamut of life's information-generating systems at any number of levels and for quite specific purposes.

But a physicist might want to say that reality itself is just like that too! Fundamentally, he might say, reality *is* nothing but "data at play," a field of pure information. Experiments and theories are just instrument readings and interpretations of the data and nothing is as finally real as the atomists would want it . . . just as in our "cyberspace"! We reply, It may well be so.[23]

In a sense, PME acts as though interested in maximizing uniqueness and differentiation in the world, while making the atomist's project both possible and fruitful. But the consequences go further than commonly expected.

If I might wander farther off into cosmology here: PME tells us that the physical universe is as large, and only as large, as it needs to be to obey PE.[24] This implies that the size of the universe is a function of its information content: once small because it was simple, and now large, in part because we are here. Here also "largeness" must be understood not simply as the maximum value on some spatiotemporal dimension, but as the difference between the smallest and largest, physically possible units of spatiotemporal measurement that are informationally relevant. On this view, as immense as they are to us, space and time together provide the *smallest* realm/room needed for everything to be itself "exclusively"—the smallest arena necessary for the playing out of history in its most information-preserving configurations.[25] The citizens of another universe would call that set of dimensions that serves this function—that best supports PME—their "space" and "time."[26]

The reader, however, need not subscribe to this seemingly bizarre cosmology to see that, in cyberspace at least, where the preservation of information will be of practical importance and where there will be limits on how much information can effectively be displayed, the more information that is contained, the larger, in the above sense, the (apparent) space will need to be. Under PME, as cyberspace increases in complexity and content, there will be four methods to have it "grow" to accommodate. We might choose one or more of the following actions:

1. Increase in absolute size (area or volume) of cyberspace by adding more "territory," by landfill, as it were

2. Increase in the range of scales at which one can operate; the equivalent to increasing the resolution of cyberspace itself, the density of information per volume unit of (cyber)space

3. Increase the amount of information coded into the intrinsic dimensions of data objects; that is, more dimensions per object as well as more values per dimension

4. Invoke the information latent in considering the positional and temporal behavior and character of more objects together; that is, dynamic configurational behavior.

The theme of *information density* announced in these last few paragraphs will return. For now let us turn to the manner in which considerably more than three or four dimensions can best be visualized and manipulated given the parameters we have set ourselves. This will have direct implications for the method described in item (3) above.

Visualizing N Dimensions In what follows we will assume that we are dealing with a cyberspace interface that allows us visually and directly to perceive data-objects in cyberspace as three-dimensional, changeable, and moveable through space and time in complete analogy to physical reality. In other words, consistent with what I have said earlier, the exact technology used for accessing/interfacing with cyberspace is not relevant. Thus we can imagine everything I will have to say here as happening vividly enough with available (if expensive) technology—on a high-resolution monitor connected to a very fast graphics workstation, capable of smooth, real-time animation of rather complex scenes. Stereo-optical techniques can be regarded as enhancements. Control by keyboard and mouse is sufficient.[27]

A tumbling arrow of variable length is (visually) an eight-dimensional object: 4 extrinsic (3-space plus time), and 4 intrinsic (3 angles for the direction of the arrow, and 1 for its length). A quivering, tumbling cube of changing color is a 16-dimensional object: 4 extrinsic again, and 12 intrinsic (3 for angular orientation, 6 (at least) for the amplitude and frequency of the quivering face-pairs, and 3 for the color (say, RGB values)). Clearly, it is possible to "see" a surprisingly large number of dimensions at play before the percept becomes unfamiliar. Considerable empirical research would be needed, however, to ascertain which kinds of dimensions, especially intrinsic ones, are easiest for us to see, remember, and attach value to independently. It is unlikely, for example, that a tumbling, quivering, multicolored cube in cyberspace would convey actually all the information it could potentially.[28]

Let us be conservative and assume that there are indeed quickly reached limits as to how much information can usefully be packed into intrinsic dimensions. It will turn out, perhaps, that only two encodings work reliably, say, color and orientation for a given geometrical object, and these only over a small range of values. Before accepting this, we might wonder: but what about object *size* and *shape*, those two most obvious visual attributes of physical things? Why and when can they not serve as intrinsic dimensions? This is worth considering in more detail.

Object size is not generally a good variable because when one object becomes large (relative to its address point, at the resolution of one pixel) then not only might it crowd out other objects in order to maintain PE, but we might be misled into reading subfeatures of its shape—say certain edges or corners—as having significance in terms of their own extrinsic coordinate values. I broached this subject earlier. Of course, this may be precisely what we want in certain situations, but then we would be dealing, in fact, not with one object with character, but with a set of small objects in some spatial relationship to each other, like a three-dimensional constellation, which is wonderful but not the same thing. As for shape, there may be limits to the distinguishability of object shape(s), especially when the object must be quite small to begin with. On top of this, many of the surfaces of a three-dimensional object are not visible (being turned away form the viewer) and these may be the very ones that we need to see.

What are our options? There are a few.

First, we can deal with many of the problems of size and shape I have mentioned by zooming in, by getting closer. The object, enlarged in our view, is isolated from the overall context. It might expand in inner detail, revealing complexity indefinitely.[29] Here we see intrinsic dimensions expand to become the extrinsic dimensions of the object now extended enough to have space within it, to *be* a space.

We may also rotate the object about its address point in any or all of three angular directions relative to the extrinsic coordinate system. If such rotation engenders change in the object, in color or size or shape, then up to three more dimensions capable of being encoded have been released.[30] We note that in ordinary, physical space, an object rotated on itself maintains its identity. In cyberspace this need not be the case, that is to say, an object rotated on itself may change as a function of that rotation. Similarly, in ordinary physical space, an object that is inspected from many angles retains its identity—that is, as it is revolved around *by* the viewer as a museum-visitor might walk around a sculpture. In cyberspace, again, this need not be the case, and the object can transform itself with our view of "it."[31] Things can get complicated here. Until research proves otherwise, I think it safe to assume that, in data spaces, both kinds of rotation—the object around its address, ourselves around the object—cannot effectively be used together to release information in six intrinsic dimensions, even if carried out sequentially and separately. I also suspect that, of the two, the first rotation—that is, of the object itself around its own address—is the more promising for the encoding of intrinsic dimensions. This is because, once carried out, the object stabilizes its identity, and any viewer motion around it becomes quite normal, revealing the object's whole shape.

This is all well and good. If, however, we wish to experience the object in its largest context—that is in (cyber)space, along with other objects—and if, therefore, it is important that the object not be so large as to obscure others, then we may need to adopt another method entirely for "releasing" intrinsic dimensions, namely *unfolding.*

Unfolding When an object unfolds, its intrinsic dimensions open up, flower, to form a new coordinate system, a new space, from (a selection of) its (previously) intrinsic dimensions. Data objects and data points in this new, unfolded, opened-up space thus have, as extrinsic dimensions, two or three of the ones intrinsic to the first, "mother" object. These objects may in turn have intrinsic dimensions, which can unfold . . . and so on, in principle, nested ad infinitum or until, at last, one has objects that have only one or two intrinsic dimensions and their self-identity left. At every occasion of unfolding, decisions are made as to the partitioning the remaining dimensions. At every occasion the Principle of Maximal Exclusion is applied.

Now, this hierarchical scheme ought to be familiar to anyone who has used the Macintosh, Open Look, Windows, or almost any contemporary GUI. When you click (or double click) on an icon, the "icon," effectively a two-dimensional data object, opens into a larger two-dimensional field or "window" within which new things can appear, including new icons. In cyberspace as we are beginning to picture it, three-dimensional "icons" unfold/open up into three-dimensional subspaces.

More than degree of dimensionality, however, the difference between today's GUIs and cyberspace is that in cyberspace the dimensions themselves (and values upon them) may not be neutral—that is, merely the actual dimensions of the monitor screen or the space simulated—but are themselves position-dependent state and behavior descriptors. It would be as though (in today's 2-D GUIs) all windows knew not only where they are on the screen but also where they "came from" spatially in the windows higher up in the hierarchy, all of which themselves know where they come from and all of which remain manipulable up, and consequentially down, the hierarchy. Right now, "windows" are almost completely undifferentiated bags of space.[33]

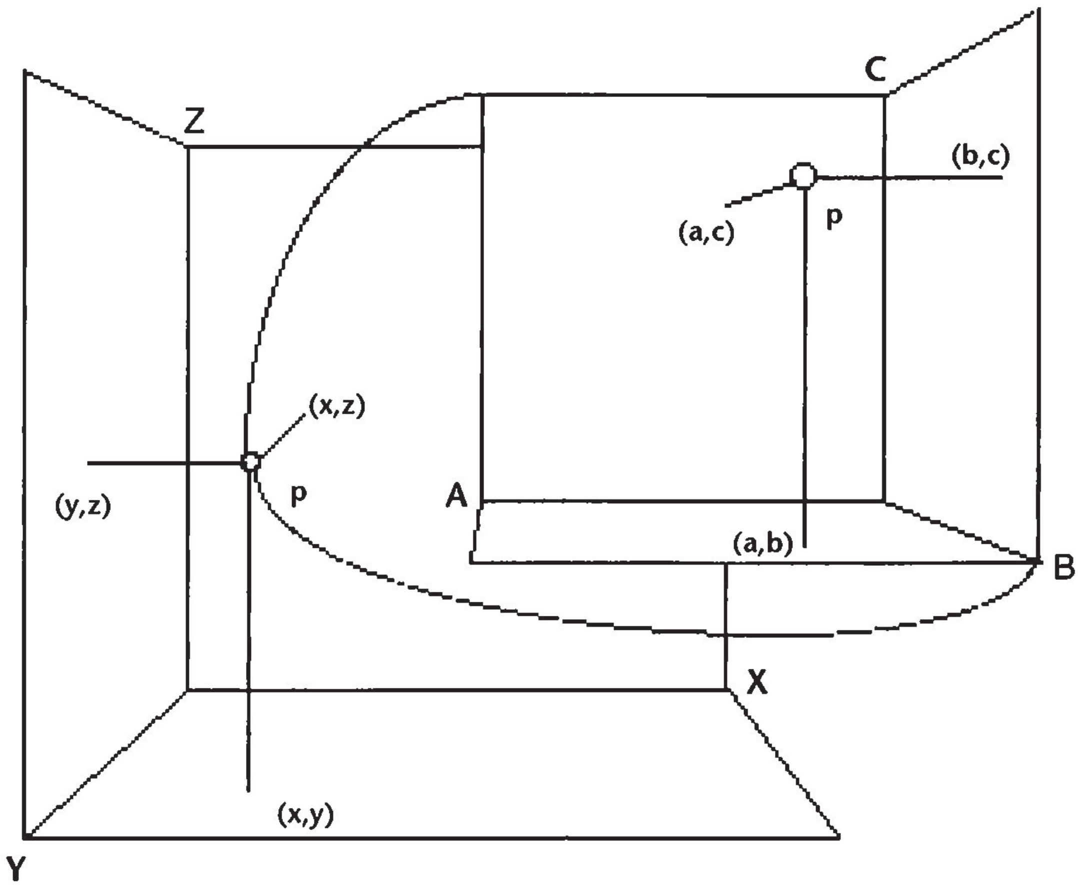


Figure 7.2
The intrinsic dimensions of the six-dimensional data object **p**, located at *(x,y,z)* in the (extrinsic) dimensional space of *XYZ*, are unfolded into the space of *ABC* and have the values given by the location *(a,b,c)*.[32] If all objects p in XYZ are identical, then motion in XYZ has no effect in ABC.

Over and above the transition from two to three dimensions implied by the move from desktop to cyberspace, the difference will therefore also lie in how one keeps track of (extrinsic) positions in such nested coordinate systems, where observer and object positions are manipulated independently. This is a considerably richer and more difficult problem than that of arranging any number of flat and sequentially dead "icons" and overlapping "windows."[34] Will there be psychological limits as to how many levels "in" one can go, analogous to the limits Chomsky found for the nesting of clauses in sentences (and that I so frequently have tested in this chapter)? In the Macintosh GUI and most others there seem to be none. But this may well be because, as each new window opens, the previous one holds steady, falling away in significance. Will this be different when all the spaces together remain "live," positionally and operationally, and interactive? It remains to be seen.

We must conclude this subsection lest it swallow up all other concerns. But not without noting that in cyberspace the possibility exists very easily to make objects whose very existence, position in space, and character are a function (also) of the position of the observer/user in relation either to the coordinate system, or to some specified third object in the space. In real life, mirages and rainbows have this quality: that is, the quality of not being anywhere reachable in absolute, geographic space, but existing nonetheless visually, and always remotely, at a place determined by the invariant spatial relationship that obtains (in the case of the rainbow) between a given observer, the sun, and the water droplets (which, of course, themselves all have stable, reachable geographic positions). These kinds of objects travel with you, or appear and disappear as a function of your own motion and circumstance. Again, only empirical research will show whether this kind of entity will be of use in cyberspace.

Continuity

Physicists surmise that in nature there may exist a certain minimum length, the so-called Plank length, $L_p \approx 10^{-32}$ cm. Smaller than this, it is thought, nothing real or physical can exist; closer than this no measurement of position can be made. The existence of L_p effectively gives space itself a certain irreducible "grain" or resolution, making all length measurements properly only numerical multiples of the unit "10^{-32} cm."[35] But mathematically, conceptually, and certainly pragmatically speaking (most of the time) true space, physical or abstract, is understood to be smooth and continuous. That is, the X, Y, Z (and T) axes of a rectangular coordinate system are understood each to have the character of the real number line—to be infinitely divisible, monotonic, and supportive of the associative, commutative, and distributive laws that underlie ordinary arithmetic operations. This is the case regardless of practical limitations that may exist with respect to real acts of measurement and representation.

The number-line character of the coordinates of physical space generally forms the intuitive and functional basis for the representation of all other kinds of axes, dimensions, and coordinate systems: it forms the *substrate* upon which these are mapped. For example, (1) although certain transformations may be applied to any or all axes in a system (making them exponential or logarithmic in numerical value, say), (2) although an axis might be made of complex numbers or the ratio of two or more variables (as when one arrives at useful dimensions through statistical, "principle component" analysis of the data beforehand), and (3) although one or more axes might be subject to "quantization" so that regions of the number line are regarded as equivalent in position-specifying function, for the purposes of visualization these manipulations merely constitute recastings of the meaning, grouping, and scaling of the numbers in the rational, number-line coordinates of "true space."

Now, it is not clear that *all* information about the world can be represented spatially (let alone ought to be). Early in the previous section it was mentioned that in order to picture the behavior of a system in a "space" at all, whether in a fully developed cyberspace or a simple data space, one had to discover factors within the phenomenon that had the character of "variables." That is, one had to define features of the system's behavior that varied in a quantitative way, of which there could be "more" or "less," "many" or "few," of which it could be said that they were "weaker" or "stronger," "higher" or "lower," and so on. This was how we ensured that we could treat variables as number-line-based dimensions, and then arrange coordinates to create and govern a data space. Happily, this is a very powerful strategy: there are few factors for which we cannot conceive of there being varying extents, degrees, strengths, frequencies, and so on. Indeed, the differences *between* variables or dimensions are differences "in kind" precisely to the extent that they are not, and cannot be, differences "in degree."

Yet there exist many reasonable sortings of phenomena and systems into "parts" and "aspects," and many useful sets and lists of "things" that are not well characterized by one or two numerical variables, although they somehow belong together and adjacent to one another. Should we wish to represent and manipulate these sorted objects in a data space, we must declare them either (perhaps unfoldable) super-self-identical objects in some neutral, unvalenced space, or, if we wish to embed them in a space with some geometry and virtual physics, we must find in them, or apply to them, some relevant numerical ordering. For example, for all the other properties they may have, *goals* may be numerically ordered according to assessed "importance" or "difficulty," *furniture* by "size," "cost," "weight," "date of purchase," and so on. (Variables not adopted for the coordinate system are, of course, available for intrinsic object dimensions and characteristics, as we have discussed.)

And if worse comes to worst, we can avail ourselves of one or more of three linear/spatial ordering systems that are fail-safe, if not always optimal or interesting, as follows:

1. *Alphabetical* Any group can be ordered by the letters of its constituent item names, which are arbitrary by the nature of language, and by the conventional recitation order of letters we call our "alphabet." (The same logic applies to alphanumeric pseudonumbering systems: for example, when stock parts each have an assigned, encoded "part number.") The alphabetic is an ordering system of last resort for almost all language-bound data, from customer lists and telephone books to encyclopedias, library catalogs, and dictionaries.[36]

2. *Geographical* Since in reality everything has to be somewhere, any information about something real—any list of functional aspects, but more especially of parts or things—can be mapped into a data space so that its location mirrors where the thing actually is or could be, physically, in relation to other things, or to the earth itself. Atlases, city maps, machine layout diagrams, engineering plans, and all computer graphic "geographic information systems" present us information in this representational ordering; and again, like the alphabetic system, it is an enormously general and useful one.

3. *Chronological* Events happen in time, often serially. A time-ordered list can be made of objects and events even if this aspect of their behavior is not truly salient. Manufacture dates, birth dates, times of arrival and departure, longevities, periodic sample values, annualized economic data, and so on, constitute in their diachronic and calendric ordering a very general mode for the construction of at least one coordinate of a data space. (A subspecies here might be termed "intervallic," that is, coordinates that map the time interval size between successive events. The "strange attractors" of modern dynamical systems theory, for example, exist in two- and three-dimensional data spaces whose axes are intervallic and twice phase-shifted from one-dimensional, time-ordered data.[37])

Arranging more or less "arbitrary" sets of aspects and lists of objects skillfully, of course, comprises much of the art of the database and database interface design; and insofar as cyberspace is just a gigantic, active, and spatially navigable database, these same skills will apply. Having thought the above thoughts, however, some future database designer with an eye to cyberspace may wish to add yet further criteria to the selection and design process. Indeed, he may approach the whole problem from a fresh perspective and bring into being an essential component of the new profession I ultimately have in mind: *cyberspace architecture*. But more about that later.

Now we return to the ideas of grouping and quantization mentioned earlier. Grouping and quantization can be used in combination. In the typical business "bar chart," for example, the vertical axis is often continuous, indicating, say, revenues in "dollars,"[38] but the horizontal axis is divided into discrete chunks, indicating, say, years. This is not to say that the data-generating (dollar-generating) phenomenon itself operates intermittently or only once a year, but that the only data measured and available has been summed (or sampled) at discrete intervals of time, namely, each year. Now, on the bar chart, a certain amount of space is simply annexed, its real horizontal dimension values divided, grouped, and banded together such that real leftness or rightness of position on the page (or screen) *within* such a grouping or bar is meaningless. All such positions are equivalent. But between bars the change is abrupt: a change in value occurs. By contrast, none of this is the case for the vertical positioning of a data point: every vertical change indicates change in value up until the quantum of the "cent" or perhaps "eighth-of-a-cent." The data space of a bar chart is thus discrete or quantized in the horizontal dimension, but (relatively) continuous in the vertical. (There are no rules here for how wide each band might be except commonsensical ones of legibility in relation to the amount of substrate, real space available, the amount of data, and so on.)

The same situation obtains for spreadsheets and matrixes in general. Here both axes are discontinuous and quantized. The location (address) and size of each cell constitute its extrinsic dimension values, the information contained in each cell space constitutes its intrinsic dimensions and dimension values. But the various positions and the amount of space *within* each cell are arbitrary and essentially meaningless. Thus matrixes and spreadsheets are only spatial insofar as their axes are number-line ordered, and only function spatially with respect to those aspects of the behavior of the system in question which lent their number-line ordering to the coordinates at the outset.

We have therefore two extreme cases to consider, *A* and *Z* (if I might use the alphabetic organizing system metaphorically!) and, between them, a quantized continuum of sorts wherein are situated the data spaces of cyberspace:

A: (representations of) physical spaces with their smooth and continuous dimensions and self-similar and self-identical objects, and

Z: pseudo data spaces that are so cellular and so arbitrarily ordered that, although they are mapped necessarily onto smooth, physical space substrates (such as screens and paper), they cannot and do not function spatially or geometrically, and whose "objects" can have little or no self-identity or self-similarity.

Intermediate kinds of spaces share to a greater or lesser degree both the fine grain and powerful monotonic ordering of natural space dimensions, and the simply pragmatic groupings of information classes, partially ordered, of structures such as spreadsheets.

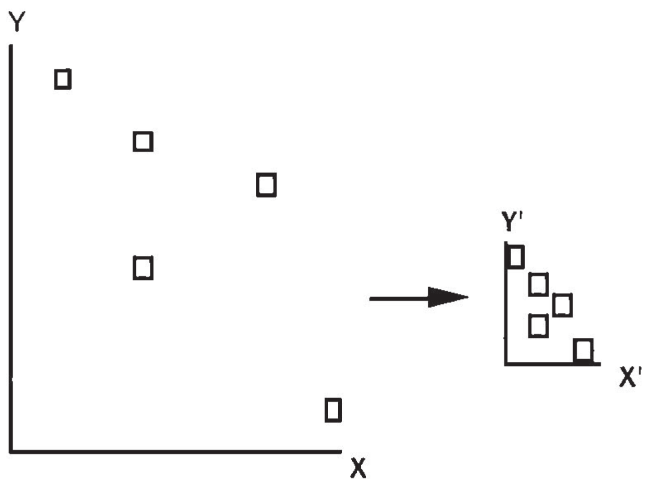
In addition, workable data spaces can result from hybrids of these dimension types. For example, one might have a space whose coordinates map *ordinal* rather than cardinal numbers, creating thus an ordinal or *compacted* space. Why "compacted"? If, for instance, we have a set of data points whose extrinsic dimension values vary from some minimum to some maximum but such that not all, or not many, of the possible dimension values are represented, then the "unused" values can be omitted. The space collapses, so that what would have been a sparse scattering of points now becomes a more compact (and memory-saving) collection.[39] Again, one may thereby lose significant geometrical information—for example, information given by the angular spatial relationships of points to each other and the coordinate frame, information that would be revealed properly only in the fully extended, cardinally ordered space.

To all of these space types, however, and to all of these permutations of continuity and discontinuity, the cyberspace dweller will bring his inherited expectations of continuous, three-dimensional, physical space: real space with its natural ups and downs, left and rights, forwards and backwards, innernesses and outernesses, velocities and efforts, causes and effects. And it is out of a rapprochement of the two systems—physical space and data space—that cyberspace is born.

Limits

No discussion of continuity can conclude without a discussion of continuity's corollary: the idea of boundary or *limits*.

How large is our physical universe? No one can say; no one knows what lies beyond the most distant visible galaxies. It is not even clear that the question is legitimate. After all, what does it mean for everything-that-is to have a size?



a) Extended (cardinal) space **b) Compacted (ordinal) space**

Figure 7.3
(Note: these diagrams also indicate a space that is intervallic.)

One conventional view is to suppose that the universe is "finite but unbounded," like a four-dimensional sphere whose "surface" (our 3-space) is continuous and never ending, but is still of certain and finite size (volume). A more radical view is to hold that there is no meaning to the idea of boundary and therefore to the idea of the absolute size of space, except in the relationship between the "smallest" and "largest" measurements that can be made. Thus "size" is actually a sort of span, a ratio, a dimensionless number **W**, say, that can only be measured in principle from inside the system. It is measured in two directions, as it were, "up and out" and "down and in" from a particular position between macrocosm and microcosm occupied by the observer. The value of **W** in this physical universe, estimated from the value of the Planck length and the diameter of the universe, seems to be around 10^{70}.

To speculate further, it may well be that the value of **W** is a constant, no matter where along the macrocosm-microcosm spectrum the observer attempts to make his bidirectional measurement. Wherever he is, no matter what size he is, there is always a universe of things smaller and things larger than he. It may also be the case that the universe is expanding not only in its largest dimensions but in its smallest too, so that when we speak of the Hubble constant and of the "expanding universe," it is the value of **W** that is enlarging and not only its outer diameter. The picture created is not of a universe closed with respect to its "geographic" volume, embedded in and measurable with respect to some higher-dimensional and/or larger vessel space. It is, rather, something more fractal in flavor; topological closure, if any, exists in the meeting of the extremely large and the extremely small on some always-other-side from the observer. We stand, thus, always at a point on an expanding "circle of sizes" where in the "clockwise" direction things larger lie, and "anticlockwise," things smaller.

Whether or not this is an acceptable account of size in nature, we will nonetheless have to decide how cyberspace terminates. Will cyberspace have edges to blackness, walls of final data? Or will it be endless? If the latter, how? Like a planet, so that traveling for long enough in the same direction we find ourselves back where we started? Or might it be possible to present cyberspace phenomenally as a four-dimensional sphere, where striking out in any (three-dimensional) direction brings one eventually back to where one started? If we choose the latter, will we be able to conceptualize and navigate it? I think not. In the second part of this chapter I propose an intuitively satisfying way of making cyberspace boundless without depicting curvature or invoking intuitions of higher spatial dimensions; this by employing the idea from topology of a three-dimensional manifold whose horizontal edges are "abstractly glued" to form a "fat two-torus." Absolute size is calculable but not perceivable to the embedded user. Magical, but minimally so, an exact description of this cyberspace topology will have to wait.

If the two-torus is a good model of cyberspace's intrinsic boundedness and shape, it leaves open the problem of cyberspace's size and of its growth? Earlier, on page 148, I outlined a number of ways to respond to these problems, having to do with information density. In the next section, with the notion of information field density, **D**, we will find a plausible translation of nature's measure, **W**, into cyberspace. With it will come some surprising phenomena.

Density

How much space is there in space? Strictly speaking, which is to say, mathematically speaking, this question is either trivial or nonsensical. There are no more numbers in the real number line between 1 and 2 than there are between 2 and 3, no more distance in a 1-inch length here than a 1-inch length there, and no more area in a 4 x 6 region than a 3 x 8 region. True points are self-identical, have no interior and no size, and they can contain no space in themselves.[40]

It would seem, then, that to propose as interesting the issue of the "amount" of space there may or may not be "in" space must be to invoke a metaphor or analogy to some physical circumstance or process of containment, and thus not to be referring to space itself. We are likely to be thinking of space as some kind of compressible fluid, like air. A bottle may contain more or less air, for example, measurable by the air's "pressure," which is directly related to the gas's density (mass, or number of atoms per unit volume). Thus, in our analogy, more pressure is equivalent to more air per unit space, which means more space per unit space. And lest we believe that density/pressure is a matter of resistance to rigid containment, we can remind ourselves that, in the atmosphere, only loosely "contained," density can also vary for any number of reasons: heat, wind, humidity, altitude. . . . Thus we are supplied with a preliminary, if naive model for our notions of variable density of "space in space" without needing to think about containment and pressure in a literal sense.

To indulge this model any further is to conceive of two kinds of space: one, which is the space in whose varying amount we are so interested, and another, which is some absolute and homogenous underlying space whose linear metric forms the datum for the measurement. If the first is called the superstrate, $\mathbf{space_o}$ ("space-over"), and the second is called the substrate, $\mathbf{space_u}$ ("space-under"), then it is easy to see that we are concerned with the ratio or difference of the two.

Density of three-dimensional space-in-space = $\mathbf{D^{(3)}} = \mathbf{space_o/space_u}$

Where $\mathbf{D^{(3)}}$ is a dimensionless number (unless one wants to think of it in units of cm^3/cm^3).

Are there really two kinds of space? (And, if so, which do *we* inhabit?)

Rather than just say no—which is eminently sensible—let us remember the heady opportunities cyberspace offers us and pursue the matter. Perhaps we will be able to devise some interesting and useful experiences in our nonphysical universe with the idea of space-in-space; but the nature of the exercise is such that we may also find ourselves gaining insight into the possible nature of the physical universe.

There are two distinct and alternative ways of having "more space in space," or should I say, having more cyberspace in cyberspace. Both involve notions of density, but they do so differently.

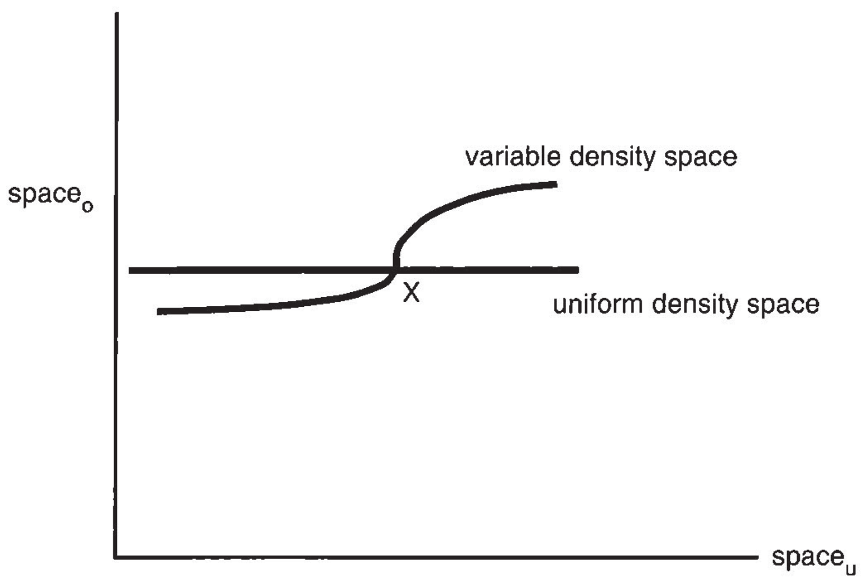


Figure 7.4
The observer is always at x, and imagines that space is universally uniform at the density value characterizing his own location.

Pixels and Voxels In the digital world of the computer screen it is easy to create models that begin parallel to our "atmospheric model" of spatial density but then help us supersede it.

There are a finite number of finite-sized pixels on any video monitor screen, and it is not unreasonable to define the real (2-D) size/area of an object as the absolute number of pixels that comprise it. An object that is moving itself or is being "dragged" across the screen will retain its size and shape because the distribution of pixels over the screen is uniform. That is to say, grain aside, the superstrate array of pixels, $\mathbf{space}_o$, and the substrate physical array of the screen phosphor molecules, $\mathbf{space}_u$, map uniformly one onto the other. The ratio, $\mathbf{D}^{(2)}$ expressed in pixels per square inch (or dpi^2) is a constant over $\mathbf{space}_u$ (to which we give the more fundamental—because universal—status). Vary $\mathbf{D}^{(2)}$, however, by physically (or mathematically) varying the size or distribution of the pixels, and the phenomenal shape-and-size of the object will vary depending on where it is. It may well shrink, swell, and change its shape in any number of topology-preserving ways. Furthermore, any traveling, one-pixel "particle" that, on a uniformly pixellated screen, would travel at a constant pixel/sec (and therefore inch/sec) *velocity*, would, to us, decelerate and accelerate as it traveled through areas of varying pixel density.[41]

More interesting is to consider two elaborations of this simple scenario: first, extrapolation into three dimensions, and second, the adoption of the perspective of an observer operating in $\mathbf{space}_o$ rather than $\mathbf{space}_u$:

1. *Into 3-D*: Three-dimensional pixels are often termed "voxels" (volume-pixel). Free of forces, all data particles or small data objects traveling through uniformly distributed voxels would behave close to the way they behave in everyday physical space (uniform $\mathbf{space}_u$). Manipulating the density of voxels, $\mathbf{D}^{(3)}$, will change the motion/behavior of the particle in a manner fully equivalent to the two-dimensional pixel case. In analogy to the Theory of General Relativity, for example, objects might reasonably be interpreted as following geodesics in "curved" space-time. (Indeed, one wonders what the notion of "curved" space(-time) could possibly mean—at least in popular physics—that could not be better visualized, if not explained, by the idea of space-in-space or spatial density gradients. Explaining

gravity using pictures of rubber sheets forming funnels for hapless marbles begs the question. After all, why should the marble spiral *down* the funnel if there were no gravitational force extraneous and additional to the geometry of the funnel that is supposed to, itself, explain/ picture/cause the gravity?)

By way of comparison, the value of **W** for cyberspace is likely to reach no higher than 10^{24}. This estimate is based on a phenomenal measure of cyberspatial Planck length, $l_0 = 4 \times 10^{-6}$m, a voxel measure, v_0, therefore, of $l_0^3 = 6.4 \times 10^{-17}m^3$, and using a geographic ordering of the earth's land surface area 250m "thick." (Real space, over the same volume, has **W** = 10^{50}.) More interesting to the designers of cyberspace is the relative ease with which the observer can always be positioned such that macrocosm and microcosm are not themselves absolute "positions" but *directions* on the "circle of scale," a possibility I described earlier (p. 151). Thus, continuous or stepwise entering into smaller and smaller, unfolding objects-turned-spaces can circle us back to the macroscale view that contains our initial position, and vice versa. This Ouroboros-like, space-within-space circularity of scale can function independently of the two-torus topology recommended—or of any other topology—for the universal cyberspace.

2. Now let us enter and dwell in **space**$_0$.

But first, consider again what it is that really governs the dynamics of objects in a data space no less than what governs the pixels themselves. Both—objects and pixels—are *rigged,* as it were, like puppets. They dance their dance according to the results of an immense traffic of calculations being carried out in the background. Here, quite literally "behind the scenes," and invisibly, they are constrained, guided, and governed by the program residing in a microprocessor. How fast and how smoothly things happen on the screen (or in the space) is thus a function of the speed and control of these intricate bit streams to and from the screen (actually the frame buffer and video RAM) and not of the "natural" imputed properties of the objects we see, or of any direct, electromechanical, spatiotemporal interaction between them. Signals from object A to object B are not propagated across the screen at some pixel velocity; they are computed by whatever equations apply—taking no longer to compute large than small distances—and the results are "posted" on the screen as object behavior.

Of course, we can arrange it so that pixels—objects, texts, cubes, molecules, critters, whatever—move and behave in ways that seem natural, that is, that simulate the real objects they represent together with their physics. But this must be done deliberately, and, generally, it requires enormous computational power to do so. Furthermore, the speed of the process is apt to be critically sensitive to the *complexity* of the objects in question—to their detail, geometry, color, rendering, and so on—as well as the sheer number of objects involved at any one time. This is *quite unlike everyday reality* where an intricate object in a crowded room falls to the floor no more slowly than does a simple one in an empty room.[42]

This said, let us imagine a different system, one in which physical reality is more closely simulated. "Distant" CPU calculations are kept to an absolute minimum. The screen is bit mapped, the space is bit mapped; the video-RAM /frame buffer is "intelligent." All influences of one data object on another are *actually* propagated in the buffer, but are *phenomenally* propagated though the pixels or voxels of $\mathbf{space}_0$ just as light and sound travel through space and air obeying the inverse square law. Objects move through space—and/or across the screen—dynamically constrained (1) by the rate at which their "information mass" can be "accelerated" and "decelerated," and (2) by the local value of $\mathbf{D}^{(3)}$.

Next we place *ourselves* subjectively in this superstrate space, $\mathbf{space}_0$, much as Edwin Abbott's Flatlanders are embedded in theirs. We have become one of the objects. We can see and know only what comes across $\mathbf{space}_0$ to us. We cannot see or know anything of the background calculations. We cannot rise off the screen, or out of the space, into a higher dimension so as to see the whole layout and thus have foreknowledge.

We are embedded specifically, let us imagine, in a three-dimensional (cyber)space of locally uniform $\mathbf{D}^{(3)}$, and it is dark. All around hang fixed "stars" and seemingly fixed "planets."

Now we see an unidentified flying data object (UFdO) moving in the distance at a constant velocity. As we watch, quite suddenly it slows and shrinks, rapidly dwindling in size! What has happened? We cannot tell.

Three interpretations are plausible: (1) the UFdO has actually slowed and shrunk, (2) it has turned and is traveling away from us, or (3) it has entered a compacted region of space, that is, a region of increased density, $\mathbf{D}^{(3)}$. Discounting interpretation (1) (that is, positing maximum object self-identity) we are unable to decide between (2) and (3). Indeed there is no method—not stereopsis, not radar—that can decide between them!

Now let us set out to catch up to the mysterious craft. Through the flat, dark field of $\mathbf{space}_0$ we fly. Around us data stars and data planets move, flowing by more quickly to our sides than directly ahead or behind, and moving more or less slowly according to their distance from us, as is normal. Two minutes later we see the UFdO dead ahead of us! It seems to have stopped moving since it grows steadily in size, following the cotangent looming curve that is in agreement with our own velocity. As we draw near, it seems less a (cyber)spacecraft than an asteroid (". . . obviously intelligent, Number One!"). We approach, and as it looms we see more: like ordinary physical things, the closer we come, the more it reveals of its detailed structure.

We notice also, however, that *our* velocity has slowed; and, try as we might, we cannot accelerate towards the object! Only up, down, left, right, and away from it can we move any faster. In fact, moving away, we accelerate, and this without asking to.[43] It is as though we have fallen into a reverse gravitational field created by what now seems more like an asteroid, a small world. Either that, or the thing is expanding in size, and with it the space around it. ("This is no asteroid, Number One, this is a *planet.* And it's growing!") How can we tell? Looking around—as we now seem only to inch towards the ever more complex planet—we notice that all other objects in the "sky" are dwindling in size, seeming to recede. Indeed, we are entering a region of *more space.* What seemed small from afar turns out to be another world; and this not just in the normal, natural sense (in the sense that getting very close to any physical thing allows us in some way to "enter" its microcosmic structure and have it surround us), but in the more radical sense that space itself has expanded, affecting both our movement and the apparent position of the rest of the world. The planet is indeed—to all intents and purposes—surrounded by a reverse gravity field, one that, at the same time as it "repels" or decelerates that which would approach it, seems to "manufacture space" in ways analogous—if reversed—to what the General Theory of Relativity tells us is the case of natural gravitational fields.[44]

What could account for this scenario? Actually, the explanation in the context of computation and virtual worlds such as cyberspace is simple.

Assume a computer of finite computational speed. It must compute and display a data object at a fixed rate of around thirty frames per second. Assuming almost zero computing load in order to translate or enlarge an object on the screen—that is to redisplay without revealing/recomputing new object information—and assuming a monotonic relationship between apparent data object size[45] and its revealed complexity, then it is clear that this finite computation speed will impose limits, alternatively or collectively, (1) on the rate of new-frame display, (2) on the level of detail and "realism" displayed, and (3) on the amount of the *increase in information* with each frame.

Since greater real motion on the part of the user generally reveals greater new information in his world, in case (3) we find the explanation of our UFdO scenario.

Of course, possibilities (1) and (2) continue to be theoretical and practical choices. They may also be functional options at the control of cyberspace travelers who could choose for themselves what to sacrifice for speed: smoothness of the animation, or detail/resolution and/or rendering niceties (such as shadows, color, etc.). Option (1), the rate of new-frame display, is a strategy common to animated video games and most "walk-though" CAD programs where "step size" can be specified; option (2), manipulating the detail or richness of the display, is the strategy of "adaptive refinement" first put forward by Henry Fuchs.[46] If, however, we wish to achieve maximum smoothness (of our own motion as well as the motion of objects "out there"), this in order to establish the phenomenologically fundamental **space**$_2$ status of cyberspace in imitation of nature, then we must forgo (1). No matter what quantization is present, inherent, in data objects themselves and in their environments, *the continuous substrate space of cyberspace is the fabric—the medium—through which* user *motion must occur.* This lends privilege to users as data objects among others: objects may perforce jump from slot to slot; but we, the travelers of cyberspace, always can glide on . . .

And if we wish to retain the maximum self-identity of data objects, we would be advised not to adopt the strategy of adaptive refinement (2) as a *norm*. For taken too far, this would violate one of the cornerstone principles of ordinary reality that would do well to remain in cyberspace and that I would now like to address (before returning to strategy (3)). Namely, the *Principle of Indifference.*

The Principle of Indifference states that *the felt realness of any world depends on the degree of its indifference to the presence of a particular "user" and on its resistance to his/her desire.* The principle is based on a simple phenomenological observation: what is real always pushes back. Reality always displays a measure of intractability and intransigence. One might even say that "reality" *is* that which displays intractability and intransigence relative to our will. This is why what is real always, ultimately, generates consensus. And science.[47]

Congruently, what is real always displays a measure of mysterious, even gratuitous, complexity, a complexity that does not adjust itself to our ignorance and that, in fact, exceeds what we know, always. More than merely something conceded to Art, this mysterious, "gratuitous" complexity, this extravagance, is reality's "calling card," its song of seduction. What is real always seems to have extra, more than we can use—more finesse, more detail, more possible uses, more reasons to be than for us alone—and we would be ill-advised, I think, to make cyberspace a place of complete knowing-through-appearances, a world where every object wears its explanation on its sleeve, and every inflection encodes some function.

The Principle of Indifference also implies strongly that, in a world we take to be real, *life goes on whether or not you are there.* This is a particularly powerful manifestation of the principle (perhaps deserving of its own name: "The Principle of Life Goes On"). To explain, the extent to which things freeze, go "on hold," simply because you are not there to keep them going, is the extent to which those things are not real. Most computer applications and games, for example, go on hold when you stop typing or issuing commands; some only when you log off. Upon your return, everything is where you left it. Things wait. In private spheres, real and virtual, this is probably how things should be, at least with nonliving/loving objects. But in public life and in common reality, the traffic of transactions, the flow of data and decisions, the movement of things, and the evolution of situations goes on relentlessly. A good part of the reason thousands participate in electronic BBS and newsgroups is because there is this kind of *life* there: life independent and indifferent, to large degree, on any single user's watchfulness and participation.[48]

Absence from cyberspace will have a cost.

The Principle of Indifference also underlies my earlier argument for the *independent* existence of virtual worlds (p. 132), for without this principle, cyberspace would rapidly devolve into countless roll-your-own realities, each as amenable to manipulation and as personal as a dream. As with a dream or an acid trip, the user himself would not believe in either the relevance of what happened there or its continuity with ordinary reality. Gone would be cyberspace's capacity to create a group of consistent worlds, let alone a single parallel universe for millions; instead, it would resemble William Gibson's *simstim* industry—VR game arcades and vacation parlors (à la *Total Recall)*, home sensoriums, rock "virtuals" on CD instead of rock videos, and the rest. The level of fantasy is not at issue here. Nor is the desirability of a multi-billion-dollar VR/simstim business.[49] At issue only is the level of malleability that is appropriate to an ongoing, real-time, consensual public realm such as cyberspace.

On the other hand, too rigid an instatement of the Principle of Indifference would be stifling and alienating. Nothing would respond to our action; nothing would "know" of our presence. In cyberspace, the individual's ability to customize his environment and his experiences certainly ought to exceed that ability in the real world. A balance must be found, and finding it will constitute a large part of the art of designing cyberspaces both indifferent and responsive, both beyond the individual and yet *for* him.[50] We will look at some of these factors more carefully below, and then again in the context of the Principle of Commonality.

Let us return, then, to the strategy of adaptive refinement. Once in cyberspace, we might wish to govern the level of detail revealed by any particular object (thus releasing oneself from its sludgy, gravitational grip!), and this by direct command to the system. We might also find it useful to *choose* to move at a desired velocity, thereby draining the surroundings of detail and rendering richness in proportion to that velocity (. . . racing through wire frames, gliding through crowded museums . . .). However, only option (3), limiting the amount of new object information per frame, will create a consistent, if unusual, realm where *phenomenal immensity follows information density*, indeed, where the laws of information itself begin to create a new spatiotemporal physics. So convinced am I of the last argument, that I propose another principle for cyberspace, namely *The Principle of Scale.* This states that *the maximum (**space**$_0$) velocity of user motion in cyberspace is an inverse, monotonic function of the complexity of the world visible to him.*

Interestingly, the real world provides some examples of the manipulation of the relationship of information density to phenomenal immensity which I have named the Principle of Scale. Traditional Japanese gardens, for example, are miniaturized, their elements representing whole mountains, seas, rivers, and trees. Because the garden is real, closeness reveals detail everywhere; because it covers itself up—offering only partial views—it discloses new information constantly. In addition, however, the movement of the viewer is *slowed*—by bridges, stepping stones, roughness underfoot, obstructions, and other devices. Slow(ed) movement and an informationally dense environment ("bits" per steradian to the viewer, and "bits" per unit volume to the planner) combine to create the desired transformation of scale, the effect of spatial immensity.

The visitor to the garden nonetheless feels powerful: his every inertially registered motion makes a difference to what he sees—too much difference, really, and this belies the garden's true size, even as we enjoy its "immensity." By contrast, the enormous, empty halls favored by the Romans, and later, for similar reasons, by Albert Speer, have the effect—in their visual simplicity combined with their slow rate of visual change at normal walking speeds and near-zero information gain—of reducing the individual in size, making him feel impotent in even this most simple procedure: walking. We have immensity stripped of information. Similar effects, and other manipulations (such as light from below, tilted horizons) that strike us deeply, will be available to the designers of cyberspace environments from the histories of designed real environments.[51]

But it is too early to be adamant. In all likelihood, all three strategies—limiting (1) the rate of new-frame display, (2) the level of detail and "realism" displayed, and (3) the *increase in information* with each frame—will find their use, and we will devise others.[52]

The Principle of Scale forms a connection between the amount of *space* in space ($\mathbf{D}^{(3)}$) and the amount of *information* in space. Following through on the idea requires us to look more closely at the concept of information *fields*.

The Information Field

In nature, space is not truly empty. "Empty space," that is, space without matter, is empty only in the classical mechanical view (before Michael Faraday). At the very least "empty space" consists of the active Higgs field in the quantum field-theoretical view, and of the electromagnetic and gravitational fields in the classical field-theoretical view. Thus the notion of a *field*—that is, of a space where every point contains, is, or has a *value* of energy, force, or information—is fundamental, especially when one believes that the existence of pure and empty space itself can only be inferred from the behavior of fields, which are themselves all that can be measured and perceived. In modern times, empty space—utter vacuum—is an abstraction. The set of laws of field behavior with respect to light and time is called *geometry*. For some, then, it seems reasonable to assert that "space" and "geometry" are equivalent terms.

Be this as it may, let us imagine a small, arbitrarily thin disc floating in Euclidean 3-space. (The space is materially empty, that is, empty of everything but the disc itself and, by implication, ourselves, the observers.) Now, the color of the surface(s) of the disc is changing over time such that we are able to say that the disc is emitting light-energy, and, further, that pattern of change of color constitutes (visual) information. Our question: *Where* is the information? To be sure, *on* the surface of the disc, but also *everywhere the disc can be seen from.*

In other words, the disc creates a *field* of the information originating on its surface extending indefinitely in all directions.[53] Or almost all directions. For there is a geometrical plane, coincident with the disc, from every point in which the disc is invisible—in other words, a plane in which the information field is null or empty. Solely from within this plane, there is no perceptible field, and thus no space, and thus no disc. Elsewhere, however, the information field is present and, unlike the energy illumination field, uniform or flat.

Now let us add a restriction. We will say that the observer has a lower limit on the solid angle he can detect or discriminate. At a certain distance from the disc that threshold is reached, and the field—now defined in terms of the character of the emitter *and* the observer—vanishes. What, we now ask, is the shape of the *boundary* of the field?

From the simple geometric theorem that states that the angle subtended by a chord of a circle on the circumference of the circle to which it belongs is a constant, we can see that the shape of our boundary is the surface of a sphere, a sphere of which the disc is a very thin layer. (Actually there are two such spheres, one for each side of the disc). Stated differently, the locus of all points subtending the same solid angle on a disc is a spherical surface containing the disc.[54] Differently again, the visual size of a disc—measured in solid angle subtended at the eye of the observer, **o**—is the same for all observers located on the surface of the same sphere containing the disc as a layer. The measure of this angle, α, is an inverse function of the square of the distance from the observer to the disc surface, and a direct function of the cosine of the angle between the observer and the normal through the center of the disc, β.

$$\alpha = \frac{\pi r^2 \cos \beta}{R^2} \quad (R>>r)$$

where r is the radius of the disc and R is the distance from the observer to the disc. Knowing one's own velocity, v, and *da/dt*, one can infer R, and without an absolute value for v, the ratio r/R is determinable.

The relationship of α to R is nonlinear, creating a field pattern that looks roughly like this for equal increments of the angle, α:

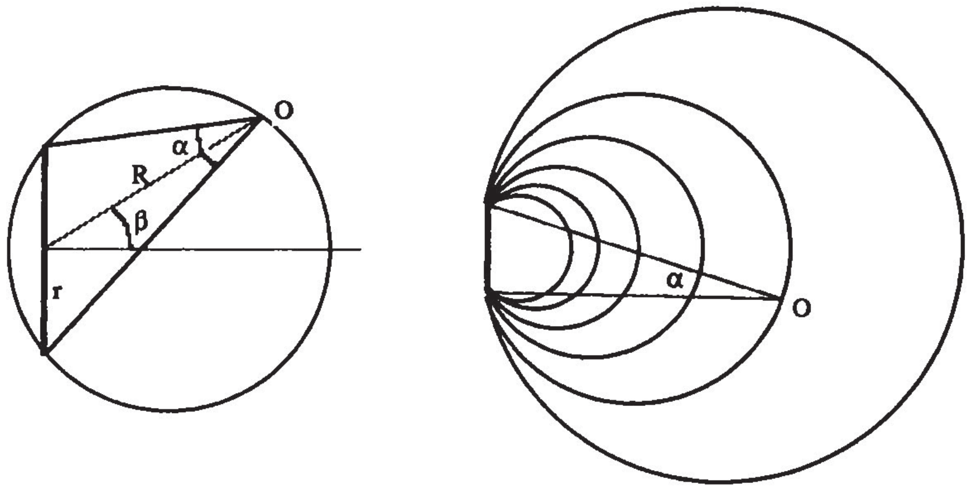


Figure 7.5
Information field of a disc in empty space.

The geometry of the field is a mapping of the geometry of the disc: different shapes form uniquely different fields; and from the field alone, in principle, one can reconstruct the fact of the disc, its size and its position. Indeed, this is exactly what we do when we see and locate anything, as J. J. Gibson pointed out (1950, 1986). The information field is thus holographic in the sense that its local parts, volumetrically, contain information about the whole. By the same token, a hologram is one kind of record of the information field, in particular, one that records/preserves/re-creates the field's original geometry over a substantial area to one side—the "front"—of the hologram. (A regular photograph records/preserves/re-creates the original field only at a point in space, that is, at a privileged "station-point" where the picture projects perfectly onto the original scene.)

Let the amount of information broadcast into the field by the disc-source, s_i, be $\mathbf{I}_i$, measured in something like bits/second. ($\mathbf{I}_i$ may also be a function of time, $\mathbf{I}_i[t]$). A measure of the *information field density,* $\mathbb{I}_i$, of the disc at the observer's position $\mathbf{O} = O(x,y,z) = O(R, \beta)_i$ is simply given by

$$\mathbb{I}_{i,o} = \mathbf{I}_i / \alpha_i(\mathrm{O})$$

measured in, or, at this juncture, thought of *as,* bits/steradian. Thus the total information available at **O** is the sum of the information present in the field at **O** from all sources, $i = 1, 2, \ldots n,$ and, concomitantly from all angles of view and all packings of a_i to the maximum 4π total. The information density of the field at a point, $\mathbb{I}_o$, is simply

$$\mathbb{I}_o = \sum_{i=1}^{n} \mathbf{I}_i / 4\pi.$$

(We assume independent information sources, a rare occurrence, admittedly.) Should there be information density *limits* on the part of the observer, in terms of his/her/its processing speed and/or visual discrimination, then certain parts of the field, beyond those limits, can be "bad," while others, within, can be "good." Set operations on the fields of more than one source are thus possible. Patterns like this can describe the way people choose seats in a theater, tables at a restaurant, and so on.

Field density measured in terms of observers and their "optic arrays" (J. J. Gibson's term) can be given further and more conventional meaning. If we are trying to find a definition of information field density as information per unit volume of space, then we need only integrate $\mathbb{I}_0$ over Δx, Δy, Δz, being that volume of space that contains the information we are interested in, and divide by the **space**$_0$ volume $\Delta x \cdot \Delta y \cdot \Delta z$, taking into account perhaps the density limitations of the observer and "shadows" created by obstructions. Indeed, the geometric pattern of obstruction-shadows, or occlusions, and the observer's geometric position vis à vis the sources of information in an environment is itself a useful class of information. This class of information is examinable in detail by my theory of *isovists*.[55]

We might now think back to the Principle of Scale and learn something more about its operation. For the total amount of information at a point in cyberspace is a sum, or, better, a union of two classes of information: the information available from other sources in cyberspace, $\mathbb{I}$, as we have just been discussing, and the information latent to the location itself, that is, figured in the location's intrinsic dimensions, which we can denote $\mathbb{I}'$.

If an observer/user happens to *be* at that point, then to both must be added a third class of information, namely, the information implicitly carried into cyberspace by the observer, $\mathbb{I}_0$: his resident files, his programs, his display and image production software, any personal cyberspace or virtual world. Even his personal intelligence and memory might also be included in $\mathbb{I}_0$, if we wish to go to the end of the argument.

When a user occupies a location in cyberspace, that-which-appears-to-him *in* cyberspace is either or both: the information content intrinsic to that point, $\mathbb{I}'$; and the information pouring in from other cyberspace entities, $\mathbb{I}$. It is up to the cyberspace system designer/programmer to make clear to the user which is which, and then also to distinguish both from the user's own, resident information, $\mathbb{I}_0$. (In the second part of the chapter, a project that capitalizes on these distinctions will be described.)

The Principle of Scale, we might now reasonably recommend, applies only to $\mathbb{I}$ and not to $\mathbb{I}'$ or $\mathbb{I}_0$ information. If we allowed the Principle of Scale to apply to $\mathbb{I}'$ and $\mathbb{I}_0$ information, we would instate a mass equivalent in cyberspace. Space itself and users themselves would have a kind of inertia proportional to their private, internal complexities, to the "mass" of the information they contained. I say "kind of inertia"

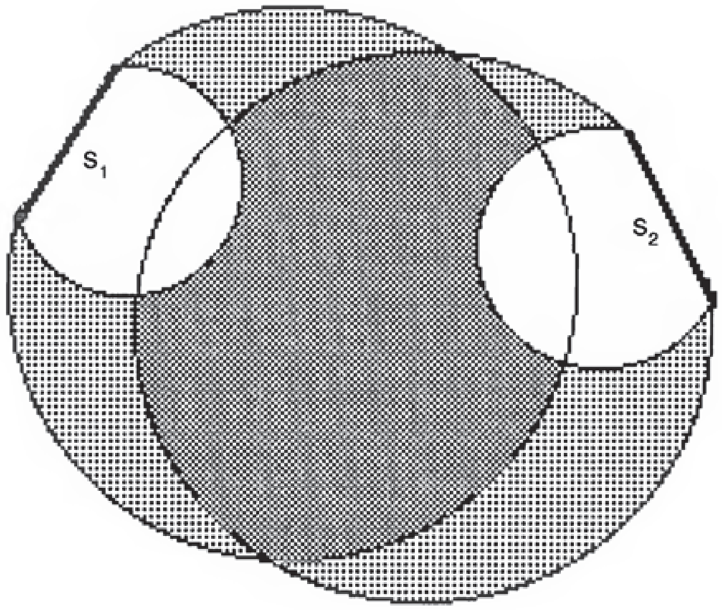


Figure 7.6
The shaded area denotes the part of the field in which the information of s_1 and s_2 is simultaneously available within the density limits set.

because affected would not be object-or-user *acceleration,* as is the case with physical inertia, but velocity. The effect would be more like *drag.*

Notice that users see each other as 𝕀 information. Notice also that the 𝕀-field is a **space**$_o$. Therefore, *the amount of (phenomenal) space in cyberspace is thus a function of the amount of information in cyberspace.* It varies objectively from place to place, is partially observer dependent, and governs motion in the predictable and yet uncanny ways we had begun to discuss.

This is not the place to elaborate further on the geometry, mathematics, and variants of (visual) information fields such as this.[56] My purpose has been theoretical and conceptual. For above all else, cyberspace is an information field most purely, and the boundary between cyberspace and real space can be designed so that the fields can extend maximally from one into the other, *geometry intact.* The intermingling of the geometry *and* content of two information fields, one electronically sustained, one materially and energically, is the goal, stated most abstractly, of all virtual reality technology: from stereo displays to the gloves, goggles, body suits, and force-feedback schemes of VR. Stated more practically: whereas standard, two-dimensional displays show the content of the cyberspace information field, 𝕀, at some point of observation, replacing the geometry of the field with the geometry of the screen, the more advanced notion is to allow the information field of cyberspace as such to extend into—and to overlay—the information field existing in the user's real world as through a window, or as surrounding him entirely. And vice versa.

The Remaining Principles

So far we have discussed four of the seven principles that I proposed earlier for the design and nature of cyberspace: the Principles of Exclusion, Maximal Exclusion (together with Maximal Object Identity), Indifference, and Scale. These were developed, I trust, in a context that supports their plausibility. I would like now to turn to the remaining three principles—namely, the *Principle of Transit,* the *Principle of Personal Visibility,* and the *Principle of Commonality,* each of which has been more or less implicit in the discussion so far.

The Principle of Transit (PT)

This principle states that *travel between two points in cyberspace should occur phenomenally through all intervening points, no matter how fast (save with infinite speed), and should incur costs to the traveler proportional to some measure of the distance.*

This principle may seem at first to be an unnecessary restriction of freedom of movement in cyberspace, too real, and too conservative (in the literal sense of the word "conserve"). After all, one of the prime advantages of network computing, and computing in general, is the almost instant access possible to the files, documents, programs, and (soon) people one is interested in, regardless of remoteness or physical location. Furthermore, the user can easily "be" in two places at once with any multitasking or window-based GUI (especially X-windows), or remote video link.

In my view, the latter facility is not contra-indicated by the Principle of Transit, whose aim is to help build and maintain a sense of continuous spatiality (in accordance with the Principle of Indifference). Simultaneous presence in multiple locations is not as destructive of the mental geography that is cyberspace as would be cost-free, instantaneous travel. Like a child playing with a doll house, one ought to have no more trouble "being" in two places at once than a guard has watching several monitors, or anyone has, for that matter, scanning and looking into a number of ordinary spaces—rooms, cubicles, cups, refrigerators, roof gardens—more or less simultaneously from where they sit. The most likely problem to arise would be confusing the perceptions *others* might have of where/who/what/how many *you* are.[57] Potentially serious, this is a problem best solved by avoidance, that is, by limiting the proliferation of aliases or clones of oneself in cyberspace to two or three, and having instead "remotes"—something like cameras, microphones, sensors, or even agents—identified as such at the remote locations and limited in their capabilities. (I can hear the objections now: "No! no! I want the freedom to be, see, and be seen anywhere, everywhere, as anything, anytime, all the time. . . ." We will discuss some of this in a later section).

From here it seems a natural step to allow instant motion between remote locations. If you have the address, dial it up, and *be there!* Why not? (Why do the crew of the starship *Enterprise* ever need to *walk* to the transporter room? I have always wondered.) But consider:

1. Access is never *really* instant. It takes real time to search a disk, and it takes real time to send a message across the country. It always takes a few seconds or longer to locate and access new files and directories, and we don't seem to mind too much if the delay is reasonable and there is something else salient to see or do. Why should these delays not be made proportional to a determinate *distance* in cyberspace (and this does not have to be a simpleminded measure), and why should that time not be spent showing/experiencing the route between, however swiftly? What would one rather do? Look at the old screen, a blank screen, or watch two-second commercials?

2. But further, I hazard that *navigating* around file structures, *selecting* paths, *accessing* different and distant computers, and so on constitutes a good deal of the pleasure of computing. This navigating, waiting, and puzzle solving, which demands imagining and feeling the system *work*, succeeds in creating the very *environment* we computer fans find so addictive. These operations already build pictures in user and programmer's minds alike; and millions of dollars have been made by taking care of how consistently these mental geographies—as simple as they are—are designed, named, metaphorized, and physically managed. Hackers may be able to do without, but if cyberspace is to be the ultimate popular computing environment, why not build upon this orienting, world-building tendency in all of us? And why not preserve the fundamental concepts of distance and velocity? Without them, one

can have only disjointed places, like lit mailboxes tossed into the dark or conjured into existence from nowhere. Without distance and velocity as properties of our virtual world, one must rely entirely on quasi-spatial and abstract connectivity structures such as menus, hierarchies, and graphs, or on remembered alphanumeric codes, and manuals, hopping about from one to the other.

3. There is a good reason to *be* in transit for significant periods of time, and in relatively public areas. For it is *between* tasks, both spatially and temporally, that one is most open to accident and incident. In the real world, chance meetings in hallways, lobbies, airports, on sidewalks, and so on are essential to the formation of informal interpersonal networks. Browsing is essential to the acquisition of new information.[58] Without time in transit in cyberspace—open, spatiotemporally coherent, and free—one is imprisoned by one's discrete task domains, blinkered and locked to destinations. Perhaps most important, one has no presence to others. Indeed, without the utility (as well as pleasure) of relatively unstructured being-in-the-world, without the opportunity to soak in information, survey the field, and gradually define one's own degree of focus and interaction, cyberspace would hardly be necessary. Nor would be cities. And nor would have been the plains of Africa two million years ago.

4. If instant access to people and information were to become endemic to cyberspace, gone would be the process of progressive revelation inherent in closing the distance between self and object, and gone would be a major armature in the structuring of human narratives: the narrative of *travel*. Destinations would all be certain, like conclusions foregone. Time and history, narrativity and memorability, the unfolding of situations, the distance between objects of desire and ourselves—the distance, indeed, that creates desire and the whole ontology of eroticism (see Heim, chapter 5)—would be collapsed, thrown back, to existing in *this* physical world only, and only as lame, metaphorical constructions, here and there, in that one.

The concept of "cost" in the context of the Principle of Transit as enunciated is purposely left open to some interpretation. If it seems reasonable to identify the cost of cyberspace travel with *time* in some way, as we have, then this is because time is indeed the fundamental currency of computing, for it translates quite directly into data-processing capability and speed, and this in turn into the real-dollar cost of hardware, network on-line time, and access privilege. However, other "payments" for distance travel may be incurred as losses (lessened legitimate demand on the system). For example, loss of resolution (as with Fuchs's adaptive refinement technique), loss of range of view, of smoothness of motion, of the presence of certain data objects, of user capability, and so on. And we need not exclude direct, real-dollar charges similar to telephone long-distance charges. As long as these costs can be indexed to cyber-geographic trip distance and/or velocity, the spatiotemporal construct of cyberspace will be reinforced, and the Principle of Transit maintained.[59]

Now, none of this is to imply that free (instant) rides between two points in cyberspace should not ever be possible; only that these transgressions of the Principle of Transit should not become the norm at any and all scales, and that their special character be retained, even ritualized, by design, culture, and economic constraint.[60] For example, a zone or sector of cyberspace might have a number of designated *transfer stations*. These transport users to other sectors very quickly, blindly, and without time proportionality to cyber-geographic distance. As in city subways, orientation information is provided at these transfer stations in condensed form.

Extending the thought, we might wonder this: where does (should) one emerge when first entering cyberspace—that is, when logging in? Does each user have a place in cyberspace, somehow his or her own, that is "home," and from which they must start out and return? Or should one be able to enter cyberspace anywhere—boom!—upon merely specifying an address. Should there be distinctions, in terms of speed of accessibility, between frequently and infrequently visited places? Should leaving cyberspace—logging out—be a symmetrical reversal of the process of entering?

By way of negotiating among the competing demands and opportunities presented here, I offer these further suggestions:

It seems plausible to have a finite number of *ports of entry*, or simply, *ports*, which, like their real-world counterparts such as ship ports, airports, train stations, and bus terminals, function as landmarks themselves, while giving all travelers a concentrated geographic, cultural, and economic orientation to the sector of cyberspace entered. A user that logs into cyberspace finds himself at the port of entry he has designated, probably in a certain, standard position and orientation, and moves off from there in a self-guided, continuous manner. There should also be special kinds of ports, namely, *gateways*, that function to connect users in cyberspace to parallel, perhaps proprietary, cyberspaces and other electronically networked entities. The three systems—transfer stations, ports of entry, and gateways—each with its own set of protocols, could selectively overlap, coincide, grow, and connect as required.

If it is acceptable to be in two or more locations in cyberspace at once, as I suggested earlier, then it follows that one should be able to travel to, and enter, a second cyber place without relinquishing one's presence in the first.

It also seems plausible that frequent trips between the same locations could be truncated. Commuting can be tiresome, and the geography of cyberspace, once learned, may not be that enthralling to the jaded user, especially when he wishes not to be open to the eventfulness of "the between."

Finally, *leaving* cyberspace should not require a retracing of one's steps, literally or functionally. One should be able to exit more or less instantly, or at the very least, on "autopilot" back to the port of entry, and so on. The user can thereby witness the spatial logic of cyberspace even as he is swiftly extracted. (By the same token, autopilot may be a reasonable way to move anywhere one has the address for at maximum speed while still being able to "enjoy the scenery.")

Forgoing autopilot, allowing instant exit from cyberspace violates the Principle of Transit quite directly, but it does so for psycho-ecological reasons. Research has shown that on their daily rounds, all hunting/gathering animals in the wild, including bushmen, take a long, convoluted route out in to the field, foraging, tracking, finding food, etc., but the shortest and straightest route home with the haul, or at the end of the day.[61] This is a deeply natural and rational pattern of behavior, surviving, by and large, in urban "hunter-gatherers" to this day. Contradicting the pattern is always a disturbing affair, producing either feelings of entrapment or stranding, or Odyssean narratives of the nightmarish, protracted return. (The film *After Hours* is a nice, modern example). Thus the quick exit option in cyberspace—"option," because clearly one should be able to go back the way one came also.

We do not have the room here to continue discussing all the myriad enhancements, permutations, extensions, and subversions of schemes for getting about in cyberspace efficiently, profitably, and entertainingly. If we did, however, each should preserve in some way, and over significant portions of space, the Principle of Transit.

Navigation Data and Destination Data Because it is a space, cyberspace seems to be very much "about" searching, finding and navigating data rather than the data itself—just as space, time, geography, and planning in the real world can seem for us to be "about" affording navigation to and from significant objects rather than about those objects themselves. Indeed, the cyberspace scenarios that occur to us most readily are of this kind—stories of marvelous travel, techniques of orientation and choice, and with not too much said about why. Taken too far, the emptiness of this "Top Gun" or "wizard-nomad" view of the spatiotemporal world—a view which holds that the world is there for us to *negotiate* both physically and informationally (in as much as reality is an endless chain of signifiers, a sequence of clues about clues)—serves to remind us that in fact there does need to be an end to traveling and a purpose to manipulation. There must be a point in time and a place where one can say "this is it," "this is what I came for," "this is what I needed to know." Cyberspace needs, therefore, to focus as much on arriving as it does on touring. It needs to provide the places, faces, voices, and displays of data beyond which there is no reason to go, that call for decision and action, that create "moments of moment." What follows is a short inquiry into this idea.

If one can imagine that the world is a single information field that comes alive, as it were, in the minds of sentient, motivated perceivers, then it becomes possible, I believe, to classify that information ($\mathbb{I}$) usefully into two classes: "navigation information" and "destination information." In the interests of euphony, I would like to rename these *navigation data* and *destination data*.[62]

Navigation data, as the name implies, is that class of information that orients us in time and space, in location and direction, that tells us of our progress in relative and/or absolute terms, that contains addresses, instructions to proceed, and/or warnings not to. Navigation data compartmentalizes and, in so doing, classifies, thresholds, and sequences potential experience. It is, in short, information that serves to organize us and the world in spatiotemporal terms.

Destination data, as the name implies, is that class of information which in some sense *satisfies;* it answers a question, delivers on a promise, rewards interpretation, engenders real-world (or cyberspatial) action. It may take the form of a text to be read, an image to be appreciated and judged, the face of a friend or colleague we need to speak to, and what they actually say; a price, a quote, a joke, a diagram, a piece of music or code. . . . Destination data, in short, is a body of information judged to be of intrinsic value, however arrived at.

Navigation data and destination data always appear together, and are often intermingled. With a change in our attitude and purpose, the one may even be transformed into the other. But typically, our attention is divided between them: now on navigation data, now on destination data; now on one aspect of the environment, now on the other. And, more often than not, those parts or aspects of the world that regularly serve these functions are designed differently. We must adopt a certain artistic or professional attitude, for example, to see a street sign for what *it* is, as a thing, in its own right. The covers, pages, layout, page numbering, marginalia, contents page, and indexes of a book or magazine, a system built upon hundreds of years of textual conventions, constitute its class of navigation data. Similarly, the stories, pictures, prices, addresses, advice, and so on constitute its class of destination data. So focused are we on getting where we want to go and getting what we want to get, that *buildings*—as works to be appreciated and read in themselves, as objects that reward questioning, as "destination data"—are effectively invisible to everyone but architects. This is because buildings and cities provide the physical world's most detailed navigation systems, and are widely perceived in terms of their navigation value alone. The distinction is similar to, but not the same as that of Marshall McLuhan between "medium" and "message."[63]

In the world of computing the distinction is even clearer; and here is one general way of looking at it.

The much heralded, punctuated evolution from command-driven to menu-driven to fully configured GUI-driven applications was, in fact, the stepwise bringing of implicit navigation data to the fore. Today it has reached the point where, as I remarked earlier, user and programmer involvement with navigation techniques—windows, buttons, icons, sound effects—has become equal to involvement with destination data techniques—visualization, interpretation, inference, decision support, and so on.

Can one have one class of information but not the other? Considered in a detailed way, no; but effectively, yes. In a navigation-data-dominant cyberspace environment, for example, one might cruise through electric grids and matrices in an infinite night, behold clouds of marvelous tinsel, fly over blossoming geometric solids, spin down spiral vortexes of color . . . without learning, knowing, doing anything. By contrast, one might stare at an old monitor, studying 23 lines of amber text with nothing navigational to do but scroll forward or quit. And the second may well be the more meaningful experience! A functional balance, clearly, is required.

Diagramming the evolution of interfaces allows us to extrapolate and illustrate what cyberspace offers as a next step:

Here, total information (available) to user = $\mathbb{I}_{tot} = \mathbb{N} + \mathbb{D}$ = navigation data + destination data. In the diagrams "navigation data" is normalized $N = \mathbb{N}/\mathbb{I}_{tot} \times 100$; similarly, $D = \mathbb{D}/\mathbb{I}_{tot} \times 100$. It is understood that the value of $\mathbb{I}_{tot}$ is a function of time also.

The cleft between navigation mechanisms and destination data are sharply drawn in command-driven and standard GUI-driven applica-

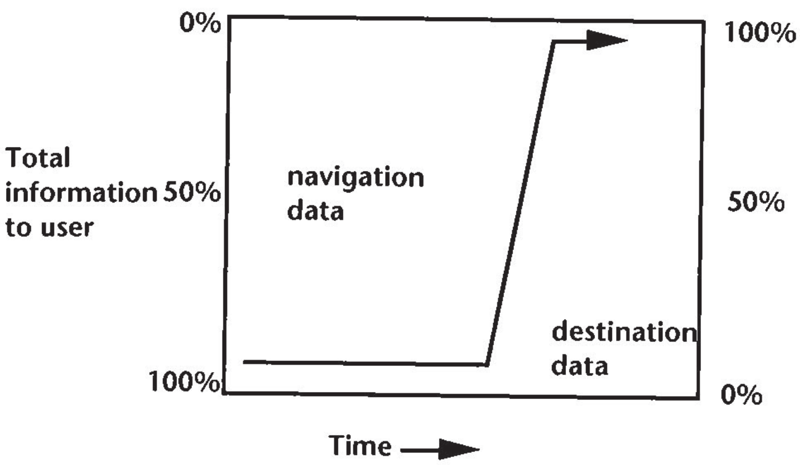


Figure 7.7a
Command-driven: a blank screen, a status line, and a few very significant commands ("navigation data") instantly give over to the document ("destination data").

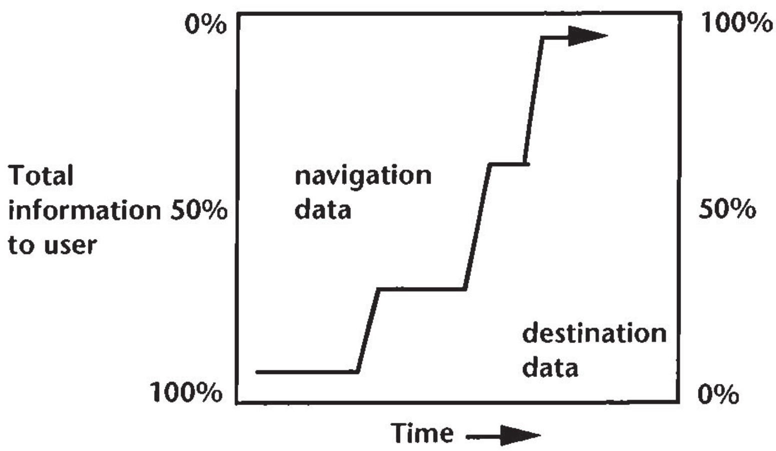


Figure 7.7b
Menu-driven: the user is given destination data in stages—its type and size, for example—by menus, each of which is orienting, sequencing, and thus aiding of navigation, until destination data fills the screen.

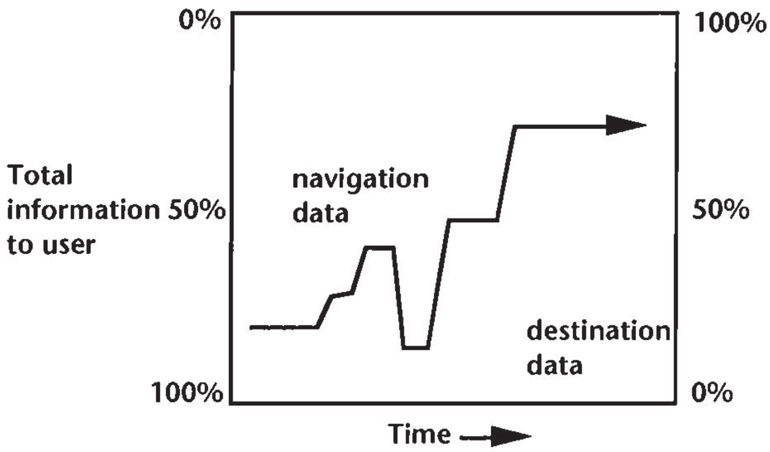


Figure 7.7c
GUI-driven: navigation and destination data coexist always, one sometimes dominating the other, but never completely.

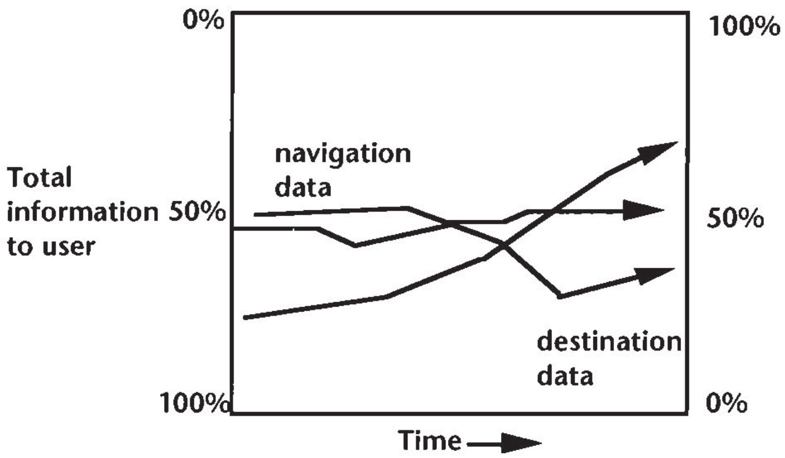


Figure 7.7d
Cyberspace (and super-GUIs): multiple destinations at different distances and different degrees of self revelation; navigation and destination data always available and balanced; tasks can involve "changing tracks of attention"; greater overall smoothness due to continuity of space in cyberspace (but steep changes—dI/dt and dN/dt >>0—still possible with destination unfolding and with step functions built into data objects).

tions. (We discussed some aspects of this earlier.) Cyberspace, on the other hand, offers a deep, spatially continuous environment rich enough for objects to be ambiguously navigational *and* "destinational"—switching, phenomenally, from one to the other as a function of user proximity, motivation, and attention, quite like reality. The red house on the corner is my home, but it is also the place to turn East if you want to get to the highway. *Seeing* in everyday life is also always *seeing-as,* as Wittgenstein pointed out; and a well-designed cyberspace will offer this kind of context dependency more or less naturally. Nevertheless, its seems likely that the earlier, fundamental distinction between extrinsic and intrinsic dimensions, including object-unfolding sequences, will map naturally onto functional distinctions between navigation and destination data.[64]

The Principle of Personal Visibility (PPV)

Based on the real world, but providing some significant enhancements, is the Principle of Personal Visibility. This states that *(1) individual users in/of cyberspace should be visible, in some non-trivial form, and at all times, to all other users in the vicinity, and (2) individual users may choose for their own reasons whether or not, and to what extent, to see/display any or all of the other users in the vicinity.*

Initially, the first provision of this principle seems to be a direct threat to privacy. But the kind of visibility I have in mind here is minimal.

A small blue sphere, say, for each person in cyberspace, indicating only his position, movement, and most simply and importantly, his *presence*, would suffice to satisfy the first provision of the principle. The user is then in complete control, via protocols too many to explore in detail here, of how to divulge any further information, either automatically or on request. There are no implied restrictions on the channels and media that might be used for interpersonal contact—voice, video, text, gesture, even VR touch—nor should there be any restrictions upon the reasons and content of the communication.[65] User-identity information need not be an essential part of the minimal presence (though it seems a good idea): anonymity is acceptable. The first provision of the Principle of Personal Visibility seeks only to prohibit individuals from "cloaking" themselves completely in cyberspace, from becoming entirely invisible.

But why? No doubt hackers will try to find ways to work in cyberspace without visible presence and without trace; certainly "sys-ops" will believe it their right, and voyeurs will feel it their need. Let us set aside the efficiencies and rewards of stealth; and let us let the watchers also lightly be watched. The Principle of Personal Visibility installs the belief that democracy, even in cyberspace, depends on accountability, and that accountability depends in turn on *count*ability, that is, on the obligation to "stand up and be counted," to *be* there, in some deep sense, for others. An open society requires the open presence—each to the other—of its people.

There are other, less ethically motivated reasons for PPV. In the real world many behaviors are guided by the grouping behavior—if you will—of others. We know "where the action is" almost instantly, and we can infer remarkably well from minimal, overt motor behavior what is happening in a social situation, "what's going down." Multiple and mutual individual adjustments of position can multiply into unpredictable molar patterns of group behavior, as researchers in "artificial life" often detail. In short, cyberspace must have street life. A good part of the information in cyberspace, as in the real world, is *in* other people, *is* other people. Further, when we step beyond the minimal presences—beyond small blue spheres, say—into the exfoliation of intrinsic dimensions presented as constructed, more or less fanciful *personae*, as will surely be the case and as Gibson so cannily depicted, the vitality of cyberspace will quickly begin to rival, if not transcend, that of the real world.

Personae, of course, need not have immediate, complete presence in cyberspace. That is to say, our "blue spheres," now strangely active, like tiny crystals or miniature flags, might unfurl, upon inquiry, into diaphanous images of beauty or power, straight from the pages of fantasy books. . . . Or they might not. In fact, it may be necessary to *limit* the scale of a given individual's presence in cyberspace. They might instead, upon querying contact, send oblique textual messages, steadily revealing information and opening channels only upon transactional agreement. The channels may open—voice, video, 3-D, color—people "gathering around" each other in twos and threes and fours . . . trading carefully in the data of human connection. (From afar, faint fractal lines might glimmer between them.)

Now let us look at provision (2) of the Principle of Personal Visibility. We may wish to feel alone, to work alone. We may wish to see some but not all of our fellow "cybernauts." Perhaps others obscure our view or behave distractingly. (I may want no self-styled, teenage mutant dragon to leap into my view when he chooses to.) In these cases there is no reason not to able to *select* who will be visible to us and who will not by various criteria: proximity, absolute identity, spatial grouping, task orientation, sex, origin, interest, and so on . . . in fact, by as many classes of information as are made available by others' public presences. This power to render others invisible (to us) is the other half of equation of privacy. For all its larger socioethical implications (for example, should we be able to screen out the suffering and protests of others?) I believe it is a provision worth transferring from daily life to cyberspace. The question revolves on the definition of public versus private domains of cyberspace as to where PPV does and does not apply.

The Principle of Commonality (PC)

Where the Principle of Indifference refers generally to the relationship between individuals and the elements of a virtual world, the Principle of Commonality extends our thinking to interpersonal communications and to the social dimension, with the virtual world—here cyberspace—acting as mediator.

Ordinarily, if you and I are in the same room, we assume that we are seeing pretty much the same things. We acknowledge, but set aside, our differences of perspective—although these may sometimes be crucial.

We acknowledge that the obstructions to our respective views are also different, that smaller objects may hide in my "view shadows" but not yours, and vice versa. But we do not deeply contest the reality or commonality of the features of the physical world so evidently *around us both*. Indeed we feel that commonality at this level is necessary to anchor, to root—and therefore to allow to grow—whatever differences in experience, feeling, and knowledge we bring to the situation. The physical environment functions as an objective datum; indeed, historically, it defines "objectivity." To refer to this by our earlier terms, environmental objects have self-identity and even super-self-identity.

In connected virtual worlds all of this can be done away with. Like people communicating on the telephone, one of us can be in a living room, the other on a beach . . . but now it will not be necessary that we really are in either. You might reach for a cigarette that in my world is a pen, I might sit on a leather chair that in your world is a wooden bench. She appears to you as a wire whirlwind, to me as a ribbon of color. While I am looking at a three-dimensional cage of jittering data jacks, you can be seeing the same data in a floating average, perhaps a billowing field of "wheat." These malleable data representations, worlds, and selves, seemingly so desirable, instantiating (at last!) our much-vaunted individual subjectivity and the late-twentieth-century notion that reality is nothing but a projection of that subjectivity, are, in fact, as much laid *against* each other as into each other. While the temptation to narcissism and deception are dismaying, the risks to rational communication are staggering. Even in the emotionally relatively neutral case of alternative data representations (let us say, of transactions and prices in the futures market) our co-respondent brokers in cyberspace, if they are to communicate effectively, must be able to co-witness and point out the salient features of all representations of the data.

The Principle of Commonality in cyberspace recommends *that virtual places be "objective" in a circumscribed way for a defined community of users.* More specifically, the Principle of Commonality requires that all comers to a given domain at a given time in cyberspace are to see/hear largely the same thing—the same place, the same objects, the same people—or at least some subsets of *one* "thing," and that the same direction considered as *up*.[66] More specifically still, the principle in-states *self-similarity* as a norm for data objects (as "mere" objects) and for human presences. It is the idea of subsets here that allows us to achieve both the realness of the everyday world *and* the magical properties we would wish for cyberspace. In set-theoretic terms, the situation is easily represented in figure 7.8.

It becomes a simple matter to ensure that both A and B are proper subsets of the domain, D. We can further restrict communication between A and B to occur with and *through* the intersection of A and B only, that is, through something experienced that is both in D and that is experienced in *common*. Of course, no cyber-geographic reality is necessarily implied by this diagram, merely a logical/informational one. If Figure 7.8 suggests how our principle might apply abstractly (which is interesting in itself), it does not help us see how cyberspace as a place—a virtual world—can partake of both the depth of purely logico-semantic structures *and* the logic of being in a real space and time. Cyberspace is nothing if not the mapping of these two realms together. For this insight we require some consideration of the theory of isovists.

Isovists In my definition of the Principle of Personal Visibility, I mentioned the vague term "vicinity" to indicate the limits of visibility. Although the actual range of one's vision might be individually adjustable, it seemed implausible that everyone in cyberspace at a particular time should, or could ever, be made visible to a single user. To make progress in understanding and implementing the Principle of Com-

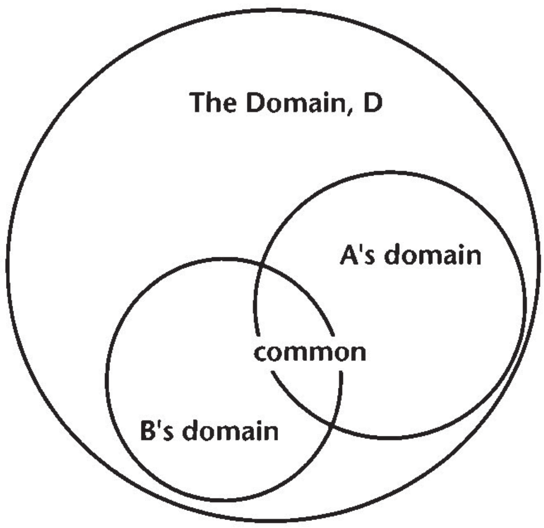


Figure 7.8
A, B, and their intersection are in D.

monality, however, we must make the notion of vicinity more precise; for commonality of experience in spatiotemporal, environmental terms entails "same-placedness" of some kind.[67] One means of reaching that precision is to use the concept of an *isovist,* and a part of the *theory of isovists* (Benedikt 1979, Benedikt and Davis 1979). Very briefly:

An isovist is defined as a closed region of space, V, together with a privileged point, x, in V such that all points in the space are visible from x. Whether an observer actually occupies the point x or not is irrelevant to the definition: isovists, like "views," are thought of as existing anyway, that is, objectively, anywhere and everywhere vision is possible. Thus one moves though the (visual) world, now "in" this isovist, next in that.

In the everyday world, with its walls and furniture and trees, isovists have varying shapes and sizes. (Only in a closed spherical room—in fact in any closed, convex room—do isovist shape and size remain the same. In this case, only the geometrical position of x relative to the isovist boundary changes.)

With this rather straightforward rendition of isovists, much can be done; and with a more sophisticated analysis of shape, even more. Here however, we can use isovists to clarify some definitions, specifically, the definitions of *concealment* and *isolation.*

Let A, B, and C represent three isovists in a domain D, with 0 denoting the null set, so that:

$$A = V_{x_A},\ B = V_{x_B},\ C = V_{x_C},\ \text{and } D = \cup_x [V_x] = \text{all } x.$$

(Of course, if x_A was in B, then x_B would be in A, and vice versa, and there would *no* concealment since observers at these points would be visible to each other.) Isolation always entails concealment, but con-

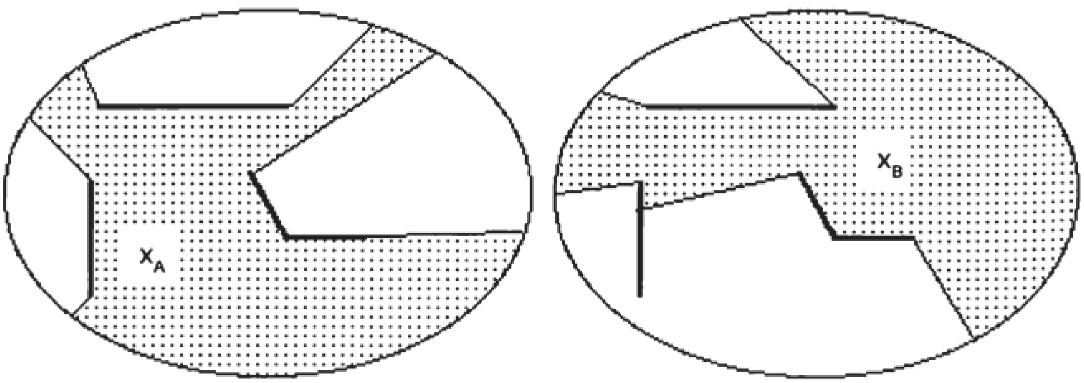


Figure 7.9
Two isovists V_{x_A} and V_{x_B} in the same domain.

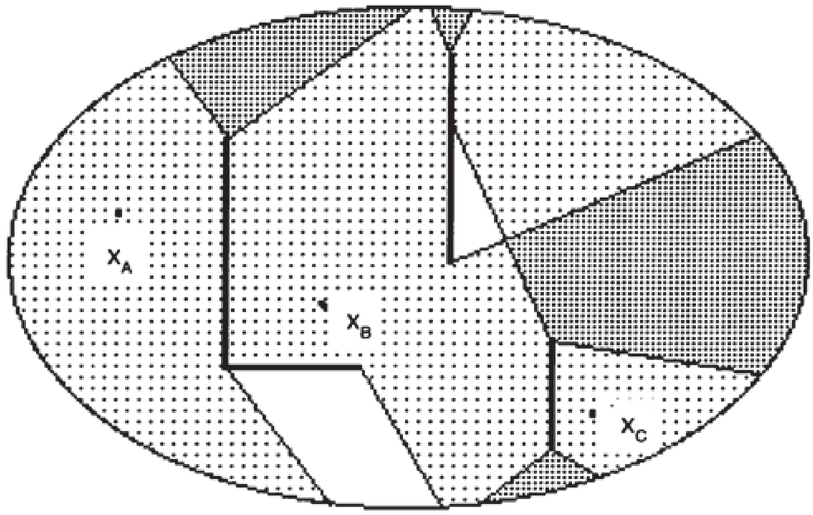


Figure 7.10
Three isovists in the same domain.

cealment does not always entail isolation. Neither isolation nor concealment are transitive relations. In experiential terms, isolation means that there is no space visible in common between you and another observer, while concealment simply describes nonvisibility.

Aside from making things clearer, these definitions from isovist theory also lend themselves to some quantification of vision-based phenomena: for example, minimal covering sets with respect to D, degrees of concealment based on area (volume) calculations, optimal trajectories to cancel isolation or to cover D, probabilistic measures on subdomains, and so on.

In the ordinary world, isovists are intricately interwoven, overlapping and excluding each other in ways that reinforce or frustrate social arrangements. Unlike our set-theoretic diagram, in real environments the intersection of $n > 2$ isovists can generate any number of disjoint common spaces, themselves distinguishable according to their common*ness*.[68] When sets of isovists are put together and become *territory* for someone, asymmetries of concealment are common. Power is intrinsically associated with places from which one can see more than one can be seen, for example. Isolation, as the term was chosen to suggest, is something few of us seek out as a norm; sufficient privacy is usually achieved by controlling (self-)concealment. In fact, the seeker after privacy will try to maximize concealment but minimize isolation. And so on.

Many are the spatial behaviors and locational choices that are conditioned by the properties of isovists in a given, real environment. In cyberspace, the situation becomes more interesting yet.

Certainly if a domain in cyberspace is merely a re-creation of the real world, such as a virtual office or store, or some remote but real location as with the technology of telepresence, then isovists behave as they do in the real world. Vision is delimited by opaque surfaces in either realm. The fact that any object in a virtual world can be a *gateway* to somewhere else—unfolding into another space, or providing a passage to another universe[69]—does not affect the logic of isovists. No matter where they lead, these gateway objects must first be seen, as objects, from the space we are in.

However, should the domain and/or its contents be diaphanous, sparse, or largely transparent, then some conventions about boundaries, about isovist *horizons*, need to be instated. For with transparency our vision is indefinitely expansive and inclusive. Objects that are close merely overlay objects further away. With our X-ray vision we could see forever! A simple solution to the problem would be to instate spherical horizons: there would simply be a limit to the range of each user's vision. A diagram of the situation would look like Figure 7.8. However, accepting some notion of horizon, and even with arbitrary levels of transparency, there still are some important differences between the set-theoretic "bubble diagram" of the situation (Figure 7.8), the real world situation (Figures 7.9 and 7.10) and the situation in cyberspace. To wit:

1. The objects collected within data spaces are not arbitrarily positioned, as they are in a purely set-theoretic representation. Instead, they follow a spatial logic of position, proximity, size, and density and are governed by coordinate systems that orient, and indeed partially create, the data objects themselves. In addition to the topology of sets, we have the geometry of data space proper.

2. The shape of the horizon need not be a direct mapping of a radial range of vision of the observer. This gives us circles and spheres. Instead, it can reach variously to geometrically demarcated "private" domain boundaries that are opaque, as well as indefinitely across common, "public" space, through openings and gaps here and there, objects within the private domain being as transparent as the user wishes them to be.

3. Certain global aspects of cyberspace's navigational systems—beacons, cardinal points, grids—can be always be made visible through any

otherwise opaque surfaces; likewise, certain classes of objects can be opaque always—for example, the immediate surroundings of one's vehicle and tools.

Thus a user's isovist in cyberspace has a hybrid character: partially shaped concretely as it might be in reality, and partially shaped abstractly by the nature of the contents of the space he is in. This hybridization appears as a patterning of transparency, translucency, superimposition, and layering. This patterning is apt to change spontaneously over time and with the user's motion, the latter either as a function of the environment itself or as a "moving property" of the world *caused* by the user himself. I have in mind here the kinds of object rotations and self-revolutions I discussed earlier (pp. 143–144); and the way rainbows always stay out of reach, or how "columns" of space keep up with you as you drive past row-planted fields (p.146). Computationally, a record must be kept at all times of exactly what is in the user's isovist by virtue of where he or she is, and of what lies within his actual view and range—this being a subset of all cyberspace objects and features potentially available for the user to experience.

Perhaps most important, however, is how the ideas of isolation and concealment, and the much more intricate patterns of *common space* that are possible in cyberspace, can be used to give order to the social experience. Here are two recommendations that instate the Principle of Commonality in a general way—the idea, as always, being to map useful, if overlooked, features of everyday reality onto the strange reality of cyberspace.

Recommendation 1: *That users cannot see into domains of which they are not a part.* Modification 1: Owner/operators of *private* domains may control what and how much of their contents is visible from "outside," as well as other, related, boundary-transparency effects. Modification 2: Items in the *public* domain are always visible, in principle, at the discretion of the user, and within the range/power of his deck. (They may also not be allowed to *enter* certain domains—but this is another story.)

Recommendation 2: *That a monotonic relationship exist between the relative volume of space commonly visible to (any) two users and the bandwidth of possible communication between them.* More precisely stated: Let $V(A)_x$ be the volume of the cyberspace isovist available to A at x, and

$V(B)_y$ the volume to B at y. Let $R_{x,y} = V(A_x \cap B_y)/ V(A_x \cup B_y)$. Let $\kappa_{x,y}$ be the maximum communication bandwidth between users at x and y, then

$$\kappa_{x,y} = a(R_{x,y})^k + \mathbf{b}, \qquad \kappa >= 0,\ \mathbf{a} >= 0.$$

Here, **a** + **b** is a system maximum bandwidth, and **b** is the residual, default bandwidth available to users who are isolated, that is, who are in different parts of cyberspace. The value of κ is arrived at empirically: it "tunes" the rate at which getting together psychologically is getting together physically.

It is worth playing out some of the experiential dynamics of recommendation (2) in our imaginations. (The experiential implications of recommendation (1) seem clear.) We understand that "bandwidth" translates easily into something like the following, *cumulative* scale of communication channels and media:

. . . text (slow), text (fast), voice (lo fi), voice (hi fi), sound (hi fi), graphics (object), graphics (paint), video (graphics/stills), video (lo res.), video (hi res.), video (stereo), video (HTP stereo),[70] VR (head-mounted displays, earphones, gloves/suit), VR ("holodeck") . . .

The system maximum, (**a** + **b**), may be reached anywhere in this scale,

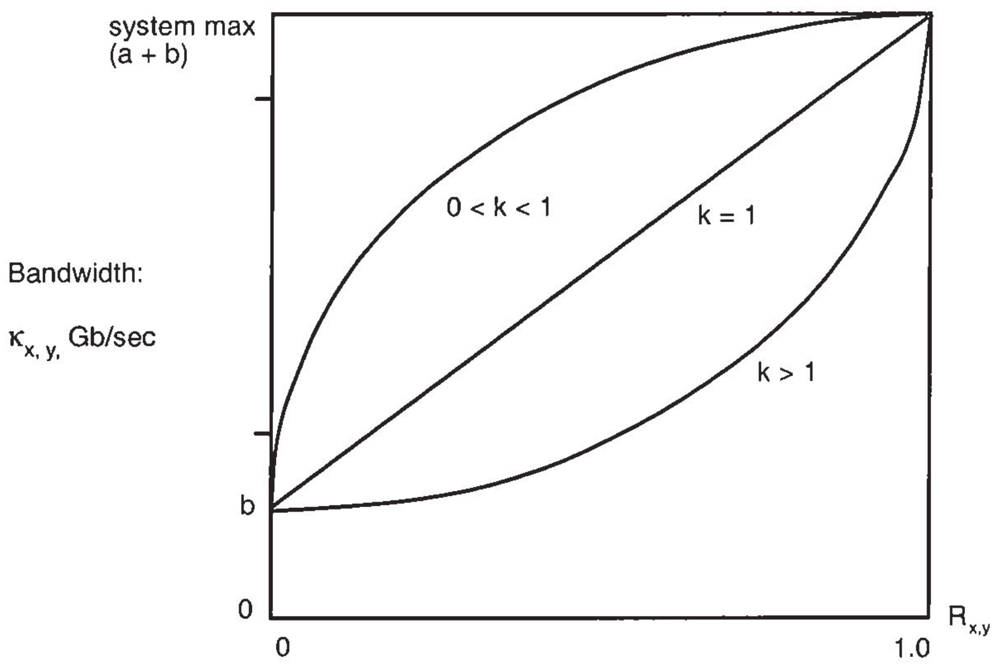


Figure 7.11
The relationship of communication bandwidth, $k_{x,y}$, to a measure of commonality, $R_{x,y}$.

depending on the whole system design, and reflects the least of either the capacity/speed of (1) the cyberspace network, or (2) the individual user's deck.

Now, the maximum value of R is 1. (I shall omit subscripts). It occurs when both user A and user B share the same space entirely. How might this happen? First, they might occupy the same point in space. This, however, is excluded by the Principle of Exclusion: they may only come "very close." Closeness is not required, however, if the space is convex and closed; that is, "being in the same room" may be enough to set R at unity. Let us imagine, however, that the situation is not quite so cozy; that with complex, phenomenal transparencies and different ranges, the value of $V(A \cup B)$ is rather large relative to $V(A \cap B)$, so that R is small. Four strategies are available to A and/or B: (1) deliberately curtail their range, (2) shut off certain views, (3) move toward each other; and (4) find locally convex regions. It is possible for two users to be in full view of each other and yet have $R < 1$. Conversely, it is possible for two users to have R very nearly equal to 1, and not be in view of each other, that is, to be concealed but not isolated from each other. The pair in the second case may have fuller communication (experientially). I believe this is as it should be.[71]

Let us say that two users are isolated from each other. Our cyberspace system has a residual communication bandwidth, **b**, and perhaps one or two media that can operate within that bandwidth. Our far-flung users *find* each other at the outset in ways similar to, but far sexier than, the ways we find each other now with telephone books and mailing addresses. Initial communications are confined to these channels. To open up fuller communication they must open windows to each other; in fact—without necessarily relinquishing where they are, as we discussed earlier—they must in effect *travel* to the other's place/space/domain in cyberspace, or to some third venue. The Principle of Commonality works in concert with the Principle of Transit, especially in the way it indexes, broadly, communication bandwidth to cyber-geographic distance.

To open full VR communications, with an individual or with a group, is to share a common reality. And vice versa. This is the very meaning of the Principle of Commonality.

We could go on. But hopefully, with this principle and all the others —individually and in concert—the reader is beginning to see how correlations between real life and cyberspace life can be maintained, and yet how much more magical and empowering the latter can be.

Part Two: Visualizing Cyberspaces

Remarks on Feasibility: The Symbolic vs. the Literal

By whatever hardware configuration, it is clear that cyberspace will require stupendous computing power and data communication speeds by present-day standards. Moreover, it will require that these capabilities be accessible to thousands if not millions of people.

When can we expect to see the requisite technology in place? Although such projects as installing the ISDN network (2 x 64 Kb/sec channels and 1 x 16 Kb/sec channel on telephone lines) and extending NSFnet (up to 2 Gb/sec, on fiber-optic cables) are being actively pursued, no one expects a super-high-speed networking system to be in place, in any widespread commercial way, before the early part of the twenty-first century.[72] Similarly, while significant computing power is increasingly affordable , the power required for color- and illumination-rendered, real-time, user-controlled animation of complex, evolving, three-dimensional scenes—around 1000 MIPS, and perhaps 4 million polygons/sec—is very far off as a common commodity.

Why, then, are we spending time, now, devising and divining the best principles for operating in cyberspace? Are we not premature? And why should we put any serious effort into visualizing mature cyberspace systems? Are we indulging in nothing more than fantasy, science fiction with an academic gloss?

In the introduction I suggested that "cyberspace" can be a motivating, unifying vision, one capable of directly coordinating, over the long term, currently disparate initiatives in computing and telecommunications. It can also motivate any number of research efforts in science, art, business, and, of course, architecture. Assuming some agreement on this point, I think there are two reasons for laying out the principles of cyberspace and attempting to visualize it now, so much sooner than it is likely to be fully realized. The second reason is less obvious than the first, and will take a little exploration. But first, the first.

Because the design, institution, and management of cyberspace will be a task of immense scale and complexity, it can simply be argued that "it is never too soon to begin." Like the early space programs of the United States and the USSR, the "cyberspace program" should begin experimentally, creating relatively crude, probably fragile, and certainly expensive cyberspaces, each with a limited number of users. As we work forward from these prototypes—improving them, connecting them—the lessons learned will be valuable ones. Spin-offs into many areas in computing—hardware, software, telecommunications, and interface design—will be plentiful. The experimental process will take decades, to be sure. But they are the same decades it will require for the technology to become affordable and for the whole enterprise to become profitable. With this strategy, at some point in the not-so-distant future there will be a happy convergence of means and ends, of capability and availability. In the meantime, the "cyberspace program" will be profitable for many: not only for thousands of engineers, programmers, designers, and managers, but for the companies and agencies that first use cyberspaces internally to increase productivity, the way Hewlett Packard now leads in the use of its own prototype networking and office automation products.

The second reason. As I have noted previously, most of the modern media and almost all of today's computer graphics and telecommunication systems—to the extent that they sustain consensual imagery, purposes, and discourses—can be seen, if not as cyberspace already, then as components of cyberspace in the making. Connected and coordinated properly, perhaps around digital interactive television, it can be argued that we have the essentials of true cyberspace in the palm of our hands already, and that we need simply to let these technologies evolve under market pressures.

Perhaps. But each of these technologies, from cellular telephones to TV shopping channels, represents an ideology and an economy with a life of its own; and the requisite coordination may never be mustered. In any event, again, we must wait.

As we await real cyberspace, however, whether it is assembled and evolved from existing networks and communication systems as just argued, or developed experimentally more or less from scratch as argued previously, we should not overlook the possibility that cyberspace as an *idea*, indeed as a *system* of ideas with rigor and purpose as well as a probable, future incarnation, can usefully inform the design of many computer applications *today*. Such applications need provide little of the direct, multisensory embrace we expect of virtual reality technologies and a mature cyberspace system, and yet they can function as cyberspace "generators" nonetheless. Just as one can, and will likely, experience cyberspace with screen-based, 3-D graphics and sound—that is, with less than full VR involvement and its attendant, enormous, processing requirements—so one can experience cyberspace "in the mind," created and sustained by programs hardly further along than today's GUIs, CAD programs, or even text-based on-line networks. Success lies in the consistency with which "cyberspace" as a functional metaphor, as a set of mental images and concomitant, real operations, can be propagated across platforms, applications, and networks. This depends in turn on the appropriate balancing of *symbolism* with *literalism* in what we design. If I might expand this last distinction:

Music can create spaces in the mind, as can mathematics. But the canonical example of symbolically created space, of course, is the space "found" in between the covers of certain books, in stories and in poems—the Siberian steppes in *War and Peace*, the desert in *Ozymandias*, the tangles of *Gödel, Escher, Bach*—in short, in the spell cast by words and numbers. If these spaces are not *cyber*spaces, it is not because they are constructed in the imagination, but because they are not constantly open to multi-use or to change, and do not themselves "know" that they are being read. But they can be "entered" by more than one person, and they can structure the discourse about, and therefore, in good part, "within" them.[73]

Symbolic systems in general—or, should I say, object systems understood symbolically—are triggers, lures, capable of eliciting rich "virtual experiences" from the mind's myriad depths with great efficiency. From the simplest of icons and abbreviations to the most enigmatic cosmological figures, symbols draw equally on our most recent training, on the decades of immediate and reported experience, and on millions of years of "neural programming." Thus symbols have enormous "leverage" compared to objects seen more purely as themselves, namely, in their literal, mechanical context. Moreover, symbolic objects themselves do not need to be very richly rendered or detailed. Drawn, crafted, gestured, mentioned, displayed on a screen certainly, symbols are energically, materially, and computationally "cheap." This efficiency, in fact, is the symbol's continued raison-d'être. The computational expense of symbol interpretation—of tracking and constructing the contexts in which they are relevant, of unfolding them into meaningful worlds—is borne by the experienced and educated individual mind in a living social context; in all, a perfect model of "distributed processing" with free hardware.

It is not symbolic but literal, "real," cyberspace that will have the insatiable appetite for MFLOPS, bus rates, pixel density, fiber-optical cable capacity, and the rest. Anything less than infinite computing power will deliver less sensory realism than ordinary reality, and less than we are apt to want. Therefore, *the question is not whether or not cyberspace should be symbol-sustained, but how much it should be so.* VR pioneer Jaron Lanier's dream of "post-symbolic communication" simply will not happen in any short term, if ever. (See Kelly 1989, Stewart 1991.) It may not even be possible. One must take what he says as a direction, a tendency, a preference, for sensory richness and literalism in virtual worlds. Indeed, rather than try to say just how literal cyberspace needs to be to deserve the name (as though we could accurately measure "literality" or "symbolicity" anyway!), I suggest the following double strategy: (1) with all technologies at hand, let us pursue establishing cyberspace as literally as possible: a multisensory, three-dimensional, involving, richly textured and nuanced virtual world converting oceans of abstract data and the intelligence of distant people into perceptually engaging, all-but-firsthand experience; but (2) let there be a sliding relationship between the symbolic and the literal, the first giving over to the second as technology and economics permit. Actually, better than "giving over": let the literal include and organize the symbolic, so that in the end *both* modes can intertwine to make one virtual world, a world that, like this world, is richer for the combination.

With this double scenario, the value of visualizing mature cyberspaces is clear. For with such images in mind, cyberspace can begin explicitly

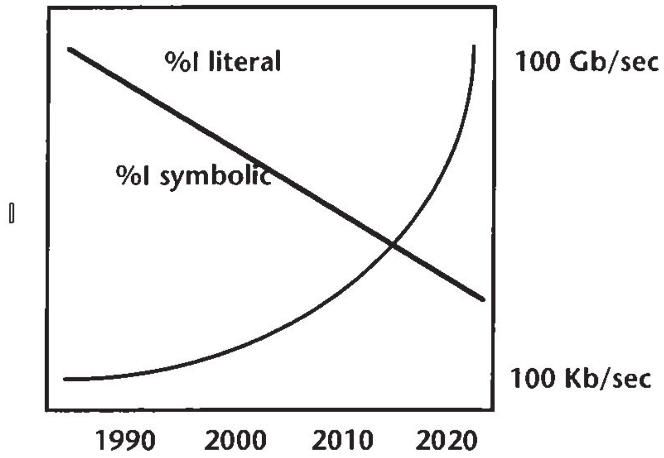


Figure 7.12
Note: here I does not distinguish between information processing and communication rates.

to be constructed, if mainly symbolically, with today's resources. Time and technology are required only for converting cyberspace from a symbol-dominated, imaginary realm to a stimulus-dominated, literal one—a realm that, furthermore, will selectively retain, contain, and transform its earlier, more symbolic parts and incarnations. What begins as cyberspace in the mind, as carefully constructed as a good novel (but now interactive and encyclopedic), steadily transforms into the world that the novel *pictures*, cyberspace itself. (And in that world, experienceable by every user that jacks in, there are "novels". . .). Natural, which is to say psychological, limits as to what can be done literally and what can be done symbolically will become apparent, as will the unique opportunities afforded by each mode, but the construct of cyberspace both remains intact and evolves.

In the next sections I will describe some explorations of how the task of designing dynamic, three-dimensional, cyberspace structures—mainly databases—might actually be carried out with due awareness of cyberspace as an evolving rather than a revolutionary medium.

Visualization One: A Visual Database

This design exercise, done with graduate students in architecture Daniel Wise and Stan George, takes as its initial problem creating a cyberspace domain that allows browsing and access to a collection of over 300,000 slides of buildings, interiors, details, drawings, and landscapes, at my institution's Architecture Slide Library. The applicability of the design, I will hope to show, is general, extending not only to visual databases such as art collections and image banks, retail catalogs, photo archives, video libraries, and so on, but to countless other databases and facilities.

The slides are currently accessed in the typical way—a card catalog (now being converted to a text database)—and a room of metal cabinets with drawers of slides organized hierarchically: by *country* or *architect* (if modern), then *building type* (subcategorized by archetypes/projects, religious, civic, residential, commercial/industrial, interiors, landscapes, miscellaneous), *allied arts* (painting sculpture, products, posters, etc.), building *location*, building *name*, and then building *view* (drawing, exterior, interiors, details, environs).

A diagram of the abstract structure looks like Figure 7.13. At the top of the (inverted) tree is the set of all images in the collection; at the

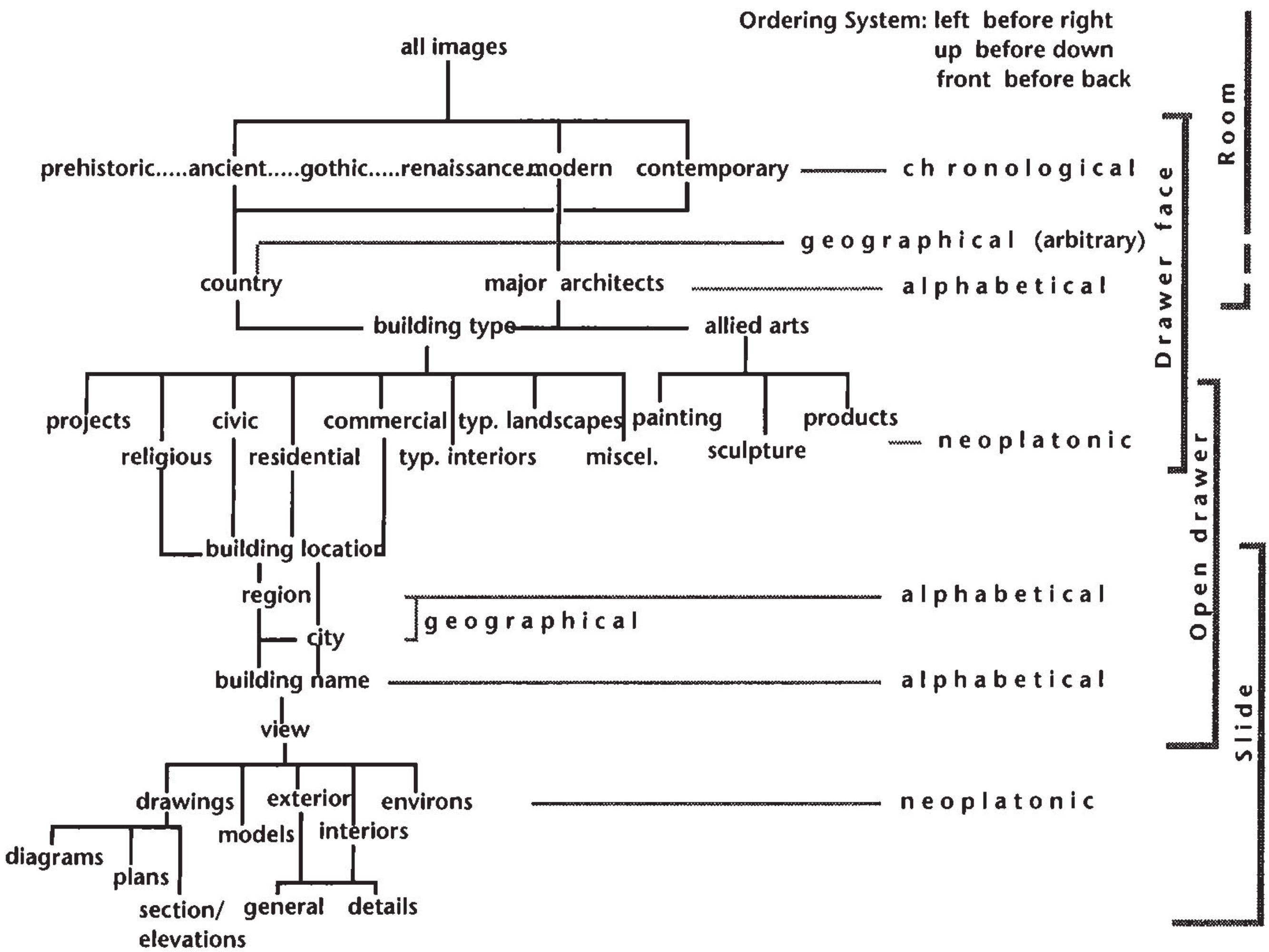


Figure 7.13
The abstract hierarchical structure of the School of Architecture Slide Library.

bottom is one image, one slide, presumably our destination. How is this hierarchical structure mapped into real space? Can one *navigate* by this structure?

First, as is typical, slides are kept in trays—metal drawers—these in cabinets, and these, in turn, in a temperature- and humidity-controlled room.[74] Access to the room is controlled by a librarian. However, the hierarchy of Figure 7.13 is nowhere to be seen, or hardly. Its upper levels only are visible on the face of the drawers; one must open drawers to see the "bottom" half of the tree. And even these are not shown in any spatial hierarchy. For in fact the slides are arrayed *linearly,* one after the other, in a long, folded, coiled row of 300,000 items, not unlike a strand of RNA or other macromolecule. (Straightened, the length of the row would be 1000 yards or 0.6 mile; side-by-side and thus directly visible the line would be 9 miles long.) The categorical hierarchy consists in markers along the length of row. To reach a destination slide, one must leaf through the neighboring slides, traveling "down" one limb of the hierarchy to the end, back up the next junction, perhaps across, and then "down" again. (The reader may begin to see the close affinity of the system with card indices and libraries in general.) Doing a search, say, for all the religious building interiors of a given period, is extremely difficult, requiring dipping into this drawer and then that. In fact, almost any search that does not coincide with the structure of the hierarchy is cumbersome. The hierarchy as a map, as navigation data, is of little use, and such usefulness as it has involves keeping it in mind and translating constantly into the physical reality at hand.

This is not to accuse our librarian, however, of arranging the slides poorly. In fact, a rather sophisticated system of orientations to navigate the tree is offered to the library user relative to the geography of the room and the cabinets, namely, the consistent if unremarkable spatial rule: left-before-right, up-before-down, front-before-back. These rules—very much prevalent in Western culture—"come" easily, and operate at the room level, the cabinet level, the drawer level, and even the slide (mount) and image level.

Interesting to note is the *variety* of ordering systems in the hierarchy of Figure 7.13 itself, each organizing a different level. Earlier we spoke of alphabetic, geographic, and chronological ordering systems (p. 148). All three are present here as well as one other—which I have named Neoplatonic, and all four read left to right as well as up to down.

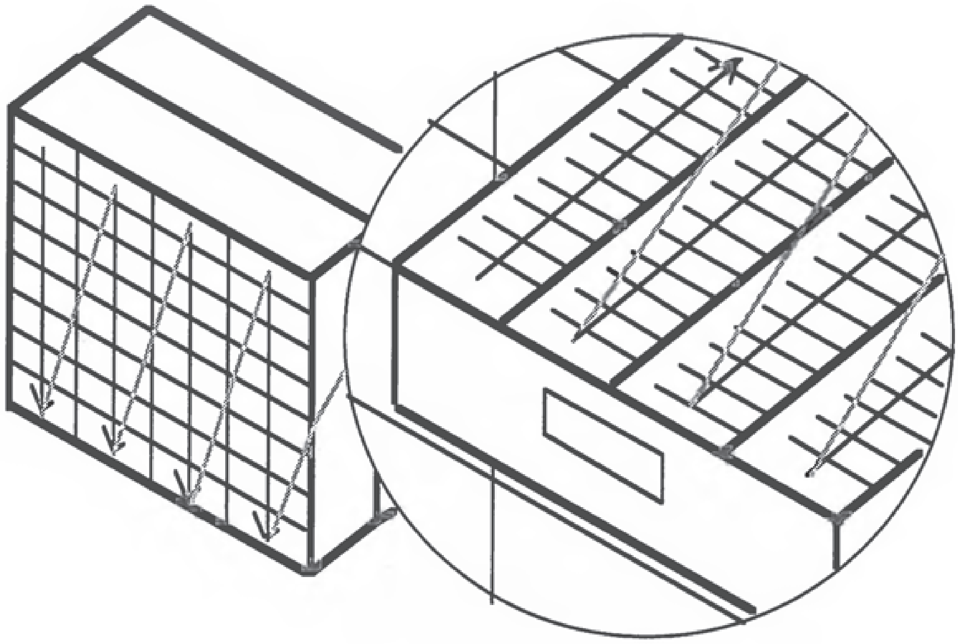


Figure 7.14a
The folded, linear physical organization of slides in drawers and trays.

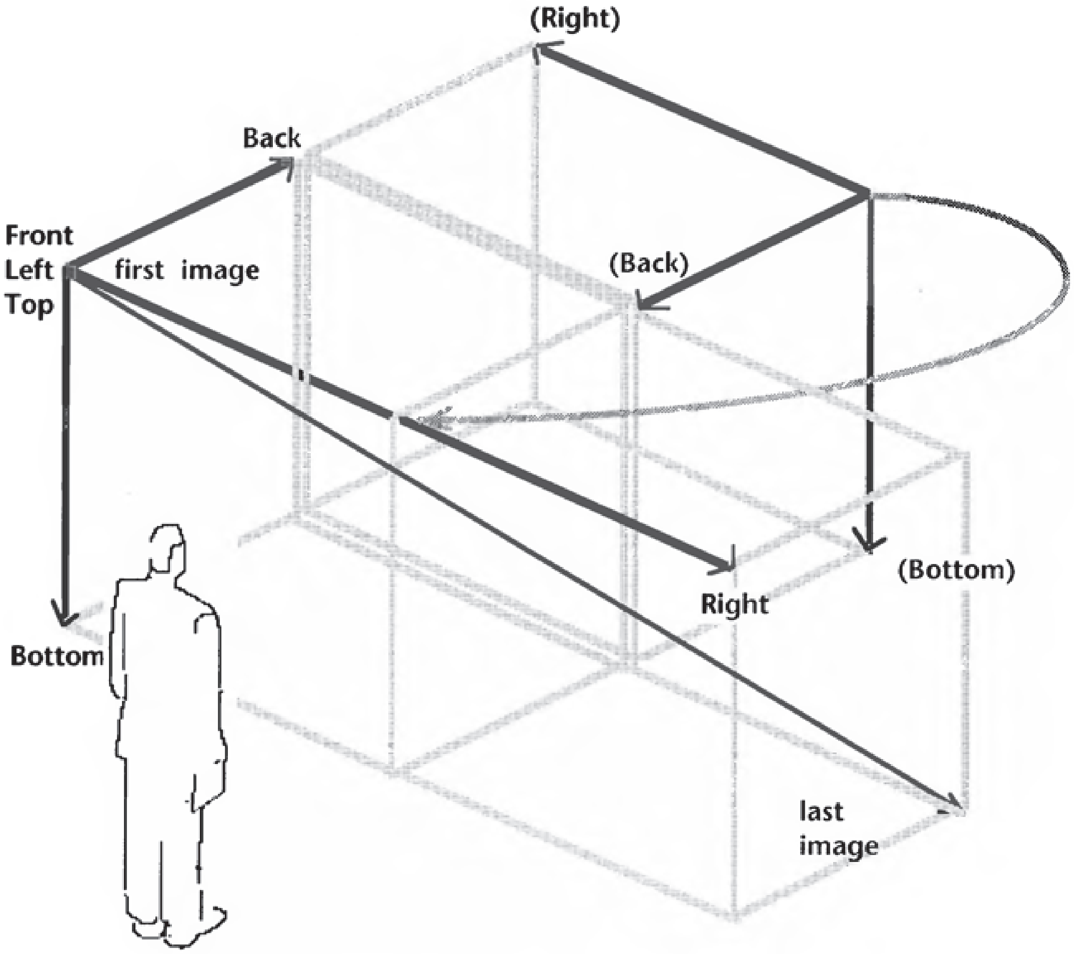


Figure 7.14b
The physical organization of the data in the room. (Note: in the real room two cabinet sets are back to back. The library user walks around to face the other way. In the diagram, the rear cabinet is swung around to complete the data space.)

What is this new scale? The Neoplatonic scheme places the spiritual above (or before) the material, the abstract above the particular, the potential above the actual, the eternal above the transient, the theoretical above the practical, and so on . . . forming a pyramid of sorts: at the top, the Forms, Truth and Beauty, God, the One; below this, angels and thought, true and beautiful things; below this, bodily existence, human and animal, impulses and instincts; below this, plant life, and below this, inert matter, earth, atoms. (Plotinus had read his Aristotle too). One can see this pattern—a value system, in fact, and one, I am sure, adopted unwittingly for being so "natural"—in the sequences in the slide library: projects-religious-civic-residential-commercial/landscape, painting-sculpture-products, drawings-models-building-environs, exterior-interior, and even diagrams-plans-sections and elevations. The fixed and timeless order of History dominates the highest level of organization, the detail of a particular eave or handrail occupies the lowest.

So thoroughly does it suffuse our culture, that I have no doubt that this Neoplatonic ordering system will manifest itself in subtle ways frequently, and throughout cyberspace.

Now, without the benefit of the notion of cyberspace and its technology, a software designer today intent upon making the library access system more efficient and intuitive is likely to want to do two things, one for efficiency and one for intuitiveness, or perhaps both. For efficiency, it seems natural to design a relational database with a textual "front end," one that can call up any image or sequence of images along any search criterion or set of criteria (from, say, an optical disc). In fact, our library is in the process of putting such a project in place. Ultimately, images will be copied rather than removed from the library, meaning fewer losses and allowing multiple "ownership" of an image. The system will be fast, will keep records, and so on, but it will be incapable of allowing soaking or browsing (see note 58) among the images, of creating a picture of a place or a period or an architect's oeuvre.

As efficient as the system may be, a more intuitive system, perhaps, would use a "hypergraphic" display of the hierarchy diagram as a map, a front end: users might click on a category and have subcategories open up, until they arrive at a series of slide names, and then images on screen to pick from. This display type, typical of more advanced GUIs, melds some of the panoptic logic of the diagram with the lattice-like, open logic, and instant, random access of a traditional database.

Now what if we extended our desire? What if we wanted to engage the library and its panoply of images more fully? After all, there are 300,000 fragments of worlds locked in our library. We want (1) to step into a virtual world where these buildings stand again, if not in true 3-D, then in good image projection, and (2) the way these are organized to be intrinsically spatial as well—a wondrous geography, a palace of places to wander through, corridors of History indeed. The basic distinction in this last sentence, of course, is between destination and navigation data respectively. Our design must somehow bring the two together seamlessly: with the ability, moreover, to navigate mixtures of chronological, alphabetical, geographical, and Neoplatonic orderings (and some forty subclassifications across these) and to construct or choose freely, according to one's interest, an *experience* of the images themselves that is repeatable, memorable, and yet unique.

I don't know that any of my students or I succeeded!

It was quickly evident that creating a *virtual building* of sorts, like a museum or "palace or places," that transcribed the hierarchical category diagram (Figure 7.13) into assemblages of rooms with doors, passages, etc., would not be efficient. Easy enough to do, coherent movement through such a model would offer none of the advantages of a database. Instead, we would be as locked into a pre-established scheme, and as locked away experientially from other rooms and the overall form of the collection, as we are presently in the real space of the slide library. Adding power and resilience to the simulation by allowing weird scaling, discontinuous motion, walking through walls, multiple presences, etc., all seemed destructive, a going-against what the notion of cyberspace and the technology of virtual reality "wanted" to do. The inverted tree had to go, and any "virtual museum"—based on it, or not—had to go too.

So a vast plain of images, the whole collection, flown over, divided cyber-geographically into landmarked regions and subregions mapping set-theoretically the hierarchical graph . . . this too would not allow reconfigurable or multidimensional navigation.

Daniel Wise's design employs the logic of higher dimensional representation discussed earlier and illustrated by Figure 7.2. This scheme was investigated quite extensively in proposal form, and indeed yielded a prototype for further work.

The user chooses a set of three dimensions to begin his search. Or there is a default set arrived at by application of the Principle of Maximal Exclusion. For example, "Date of completion," "Name of architect," "View," with the implicit ordering types: chronological, alphabetical, and distance,[75] respectively. These are displayed in a unique way, which is to say, pairwise in a three-dimensional volume, rather than truly three-dimensionally. Let me enlarge on the uniqueness here.

It is common in scientific visualization to present three- and four-dimensional data points in a coordinate system space where three of the dimensions are extrinsic, that is, are reflected in/as position in the space, and one is intrinsic (usually color).

Using this method, the space itself is often opaque with its own data, filled with a solid fog. Indeed, it is more like a solid object than a space.

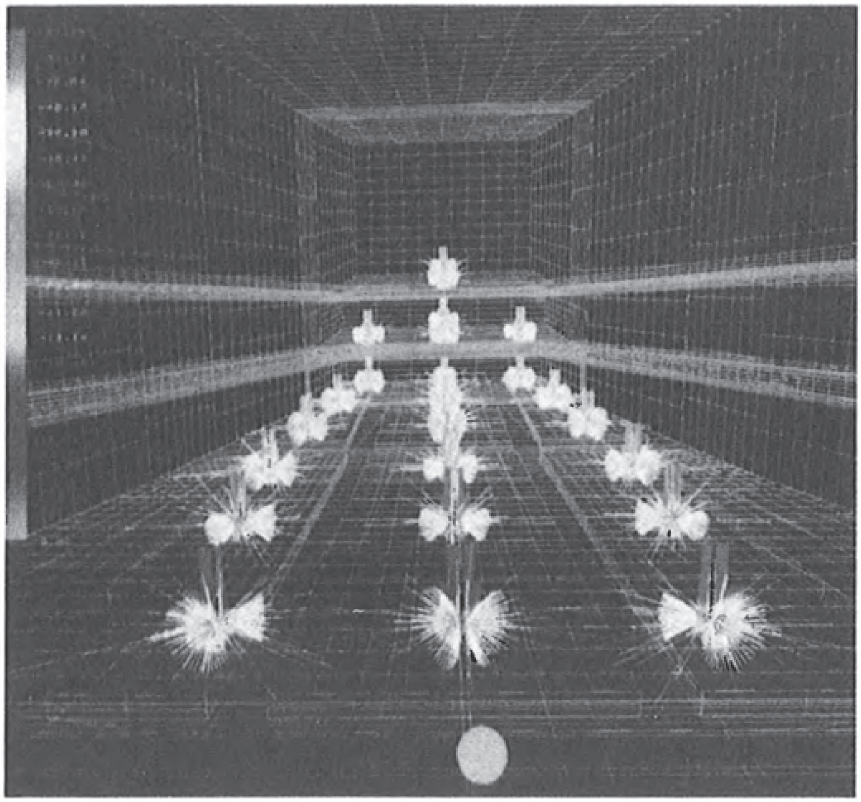


Figure 7.15
Nearly a dozen parameters displayed in the simulation of the acoustic qualities of an auditorium. Image by Adam Stettner and Donald P. Greenberg, Cornell University, 1989.

It must be peeled and sliced to see within it, examining its anatomy, and the facilities to do just this are common to all advanced data-visualization graphics packages. But how can one *inhabit* such a thing? Imagine a room so densely hung with strings of colored beads that one could see no farther than one or two beads away in any direction no matter where one walked. Nonfunctional, and suffocating. This is what it means to collapse too soon the navigation data carried by the presence and valence-structure of the "room" with the destination data, the colored beads themselves—the fog—in the room.

In our scheme, this problem is avoided. The walls of the room—we called it a "cell"—correspond to the three planes constituting a conventional, rectangular, and Cartesian coordinate system, namely, the horizontal plane, the "floor" (X-Y), and two vertical planes, the "walls" (X-Z) and (Y-Z). (It will be apparent later why Z is chosen for the vertical dimension.) The space in the cell itself is almost empty: "almost," because it contains *us*, our *vehicle*, and a *probe*, more about which soon.

Now, the walls of the cell are not blank but display quasi or partial destination data, namely, the *amount* of information, **H**, in units of megabytes, in the entire slide library that is selected by that particular value of X and Y, or X and Z, or Y and Z as the case may be, and under one of two user-definable conditions: (1) *regardless* of the currently selected value of the remaining third dimension, or (2) *given* the currently selected value of the remaining third dimension. This amount, **H**, is represented in one of three graphical forms depending on the dimension-type combination: continuous/continuous, continuous/discrete, or discrete/discrete, either as a colored and/or low-relief field, a set of ribbons of variable width[76] or a plane of discrete rectangles of variable size. Technically speaking, any one of the walls may in fact be ignored: the three dimensions are adequately determined by any pair. But the destination data a wall displays, uniquely, might well be missed.

We have a rectangular cell of an absolute size we can sense only by the application of the Principle of Scale: the speed of our subjective movement within it. And we *can* move within it, flying, floating, looking at any part from almost any perspective, from our vehicle: a virtual "pod" of some design that, with us always, provides us with interface and motion controls, navigations aids, communications devices, and many of the common features of GUIs. For the vehicle, the boundaries of the cell are not the walls however. They extend a determinate amount beyond, and with a specific geometry, shown in Figure 7.16. This permits a view of two and a half full walls (and about the equivalent vertically, involving the far wall, the floor, and ceiling) with an angle of view maximum of around 75 degrees. (Experiments have shown that this envelope is about as far outside of a room as one can choose a viewpoint and still feel inside the room, and the maximum angle of view representable without significant distortion. The near wall is transparent always.) Notice that within the envelope any amount of horizontal rotation of view is possible, except as curtailed at the corners "p" and "q," and at the boundary itself, where fuller rotation would cast us outside the cell. (Later we consider what exactly *is* outside.) However, keeping the line of regard parallel to a cell wall might simplify the computations involved, as one generates "one-point perspectives" only in this way, and it makes targeting easier in general since one's position in the X-Z plane is inscribed on the far wall "dead ahead" as in View from A of Figure 7.16.

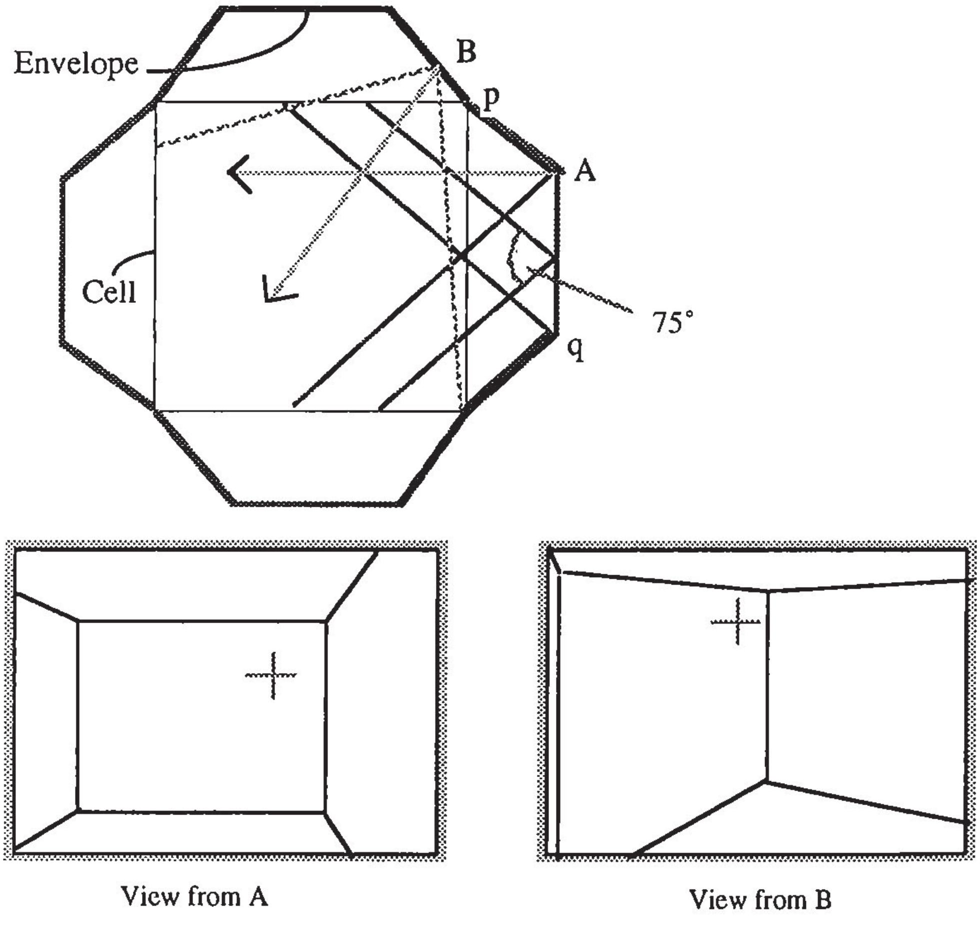


Figure 7.16
Implicit vehicle position envelope around prototypical cell for cell interior views.

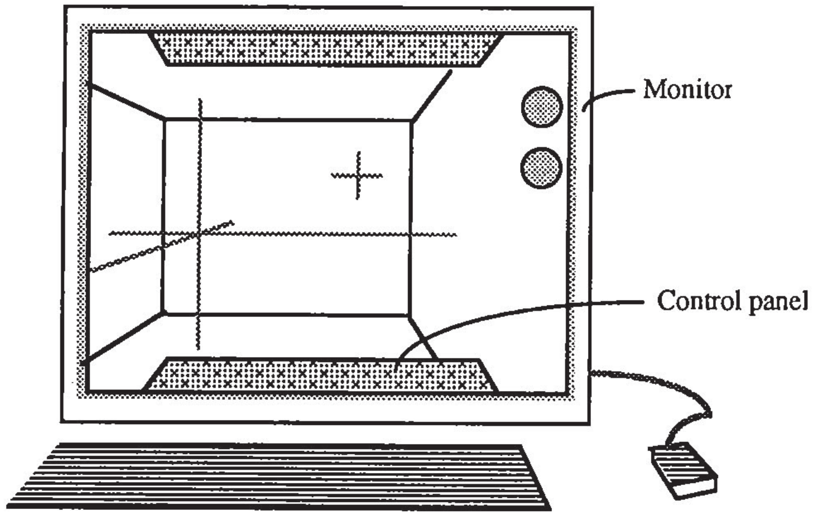


Figure 7.17
Screen-based deck system (very schematic).

One might imagine that VR technology such as head-mounted displays would obviate many of these framing considerations. Certainly the vehicle envelope could be coincident with the cell boundaries, but constraints on angle of view and freedom of rotation—especially in the vertical plane with pitch, yaw, and roll—would still need to be instated for the sake of avoiding vertigo. As well as providing a much-needed functionality, the metaphor of the vehicle gives us a legible system of motion constraints. In fact, and in whatever way it is designed in detail, the literal frame created by the vehicle and its control panels provides an essential, intermediate frame of reference between us—in this real world—and cyberspace. It belongs ambiguously to both.

The "probe" is imagined to be a satellite of the vehicle, controlled by its pilot, the user. It functions as a three-dimensional cursor within the space of the cell. The probe itself is located at the intersection of three cross hairs. It is moved by "clicking" on it and "dragging." (The mouse may be any multidimensional controller, or simply a two- or three-button mouse). Thus the vehicle's position relative to the cell and the probe's position relative to the vehicle (and the cell) is user controllable.

Now the actual information available at the x,y,z coordinates selected by the probe—the image we wish to see or the set of images we wish to browse—is not yet visible. This data is intrinsic to the probe and must be unfolded. As shown in Figure 7.2, this is easily done. Up to three more dimensions of search become available simultaneously, active in a subspace that unfolds from the probe that has its own subprobe. Upon the far wall of this subspace—or anywhere the user chooses, really—the image or set of images appears. The user now sees not only his destination, but also the structure and "geography" of the space wherein the information is stored. Both spaces and probes remain hierarchically active: moving the first probe changes entirely the contents of the subspace, while moving the subprobe changes the display only in the subspace. This continuing "live-ness" of the spaces is precisely what was called for earlier in my discussion of GUIs and windows (p. 145). The subspace as a whole can be moved forward and backward, left and right, up and down, as is convenient. It can also almost fill the screen, this in one of three ways: (1) by bringing the vehicle up closer to it (since the subspace itself is floating in the cell), (2) by bringing it up close to the vehicle, and (3) by direct screen enlargement.

A full description of the interface and guidance system would take up more space than is reasonable here. The system is rich in potential, as I hope the reader can begin to see. Almost all of today's two-dimensional GUI facilities are available "inside" the vehicle from its control panels—for example, windows and menus can pop up from the lower, or slip down from the upper, consoles. These facilities are thus not so much superseded as included in a more evolved system.

Finally, a vital aspect of operating in cyberspace is the presence of, and interaction with, other users. By the Principle of Personal Visibility, any user can be made at least minimally visible. His/her vehicle location and probe behavior is public. Every user has communication facilities, of course, including text, voice, video, and even VR, acting under the Principle of Commonality, as was earlier described. Illustrating the presence of others is not attempted here, however.

Plates 1, 2, and 3 show Daniel Wise's 1988 rendering of the ideas. Indications of the user's vehicle and control panels (the shaded frame on Figure 7.17) are omitted. A functional computer prototype of this model is currently being undertaken.

Extending the Model

The idea of a data cell is quite general. Owned and maintained in some way, it corresponds to the idea of *property*, of real estate, and we can expect some part of the economic system of cyberspace to revolve on dealings in such property. There are little or no restrictions on what can be experienced in a cell, and because it is cyberspace, there is no real restriction on its phenomenal, visual *size*. This, by the Principle of Scale, is a function of the amount of information visible in the cell, and there is no restriction but a technical and economic one as to how much and how rich this information can be. (Its auditory size is another and very interesting matter). In addition, there is no limitation on the number of *subcells* that can the opened and/or entered, except this: all subcells are entered from above. The reason for this limitation will become clearer shortly.

We imagine the cell multiplied: hundreds of them, thousands of them. We lay them out on a plane, like squared paper, their volume below the level of the plane, somewhat like a honeycomb. This is a rendition of the Matrix (Gibson 1984). Although, indeed *because*, the cells can be so different in phenomenal size once entered, their size on the surface can be more or less equal. I say "can be" because they need not be. Just as in the real world, the size of a "plot" of cyberspace is itself information: about the power and size of the institution that owns and operates it.

Some institutions (businesses, corporations, individuals, services . . .) may own several sets of cells. When these are adjacent, a transparent superstructure, a structure above the plane of the Matrix, may be erected. These are custom-designed within a pyramidal envelope to maximize visibility of them and past them simultaneously, and to correlate height with coverage.

To enter a cell is to descend into it, once permissions have been obtained. Not everything within is visible until one enters: hovering above, preparing or deciding whether to descend and enter, one might see only outlines of what lies within the cell, or one may see clear down, or one may see a special display . . . all this depends on the owner of the cell and his architect.

The cell displays default information along default dimensions. This is the state one finds it in. The user may, however, reconfigure these as required just before he descends, or while within.

Some cells might contain the kind of wall markings described earlier (in connection with Wise's visualization of the slide library) and might operate in similar ways to allow users to search them. The system is quite general. Others may use the opposite wall for data display directly—a grid of real-time video images, say, of the people who work for the institution—and use the floor and one side wall for choosing three-dimensional data points with their probes. Then again, objects and scenes of interest may simply materialize in three dimensions in the space of the cell, transparent or opaque. All the while, the vehicles and probes of others hover and move around like fireflies; and, looking up, one sees their traffic above the plane—the plain—of the Matrix.

How does one travel from cell to cell, from one landmarked or colored region of cyberspace to another without violating the Principle of Transit?

In general, one cannot simply break through to a neighboring cell. This would be an unnecessary violation if it were owned by someone else.[77] (Nor can subcells invade that space perceptually; hence, in part, their restriction to the cell floor.) Large-scale motion is carried out in two ways: by instant teleportation between transfer stations (cf. pp. 172), and by smooth flight. This flight is unique, however, in the way it amplifies everyday expectations. The "sky" over the Matrix is layered by *velocity zones*. The higher one travels, the faster one can move. The higher one travels the less there is to see: the tops of distant sector and region beacons, the iconic crowns of the superstructures of the largest institutions, the Matrix far below.

Actually this is not quite true. One may see as much information at high altitudes as at any other level. The difference is that at high altitudes the objects that *are* seen are at considerable cyber-geographic distance. That these objects are also likely to be fewer in number, and simpler, is coincidental. Here we see the power of the Principle of Scale: for the enormous sky becomes small by virtue of our speed, and yet does so "naturally," no matter how full it is visually. Thus, travel between distant parts of cyberspace can be all but instant, and the Principle of Transit is not violated.

As one descends, and slows, the Matrix fills in with detail, until one is cruising gently over the cells, looking down into their glowing, teeming, glittering interiors: here a performance, there a busy market, here a library, there a cell mysteriously empty, large, blue. With resolution on "full," we let our vehicle accelerate and decelerate as it will as it rides through the density waves of **space**$_0$.

And what is the *topology* of this cyberspace, so closely modeled on a city? Does it simply peter out into desert darkness?

Certainly, the vertical direction is accounted for. It is open-ended, and it maps the global dimension of "generality-specificity" from above to below. Indeed it does so into and through the primary cell floors. (Phenomenally, the floor of one cell can stretch a great distance, creating a surface almost as large as the whole Matrix above). In the horizontal plane, however, the plane of the Matrix folds back on itself in every direction, so that traveling in the two o'clock direction (and here clock directions make more sense than cardinal/geographic directions) finally brings one around to the same position, approaching from the eight o'clock direction. The Matrix itself can have absolute coordinates and addresses, somewhat like longitude and latitude but which never converge at poles. The overall topology of the "plane" of the Matrix is thus, technically, that of an *abstractly glued two-torus*, as mentioned earlier (p. 153). No cyberspace traveler however, sees the torus. She sees only a terrestrial geometry of plain, horizon, and sky.

Finally, in this all-too-brief sketch, it may seem that the "air" above the plane is rather empty—just translucent geometric forms all too reminiscent of office buildings. This is not the intention. One must imagine this space, first, alive with traffic—traces of hundreds of cyberspace travelers on free trajectories, clouds of sparks, perhaps glowing more brightly as they enter the pyramidal envelopes, as though entering a spotlight, or perhaps, in some, blinking out—and, second, alive with entities licensed to inhabit this public realm, floating like ribbons, hot-air balloons, jellyfish, clouds, but in wonderful unlikely shapes, constrained only (1) to represent information systems in the public interest, and (2) to be mostly transparent. There would be a thousand words and images, a din of voices and music (and, yes, advertisments are possible) . . . all to be tuned in or not, at the traveler's discretion. And, of course, the geometric forms themselves can be vastly elaborated and individuated even within the constraints mentioned.

Plates 4, 5, and 6 were developed by Stan George in 1989, using Arris CAD software. They begin to describe graphically only the framework of what we have been discussing. Much of the richness of content is missing; this was a preliminary exploration. Nevertheless, the reader should begin to get a feel for the whole.

Some Variations and Alternatives

What follows are very brief introductions—extended captions, really—to the visualization efforts of a few more of my students at The University of Texas at Austin. Many were created using computer graphics, but none were created solely with computer graphics. Like the previous projects, they are themselves far more suggestive than they are descriptive, more defining than definitive of cyberspace's possibilities. Needless to say, none of them literally work in a real-time, computational sense. They are what they are: partial visualizations, "artists impressions," if you will.

James Rojas, 1988: This visualization addresses the problem of the architecture slide library also, providing a model perhaps a little less generalizable than the one already discussed. It is based on the observation that *styles* in architecture are historically cyclic—from classical through mannerist through baroque, rococo, primitive/romantic, "gothic," and back to classical, which revives its earlier expressions and values, and so on. The process is one of codification and purification, tinkering, elaboration, decadence, exhaustion, return to "beginnings," development, and new codification . . . a process without beginning that may take centuries or decades to repeat. In cyberspace, this cycle is directly rendered as a helix, spiraling upward in time and enlarging (hence the spiral form) as more works of architecture are/were built and recorded. The whole "theory of cycles" was adopted as a conceptual, navigational scheme with full knowledge of its limitations, but with the hope that it would, nonetheless, produce a useful and memorable structure in cyberspace.

Rojas's visualization shows the overall form of the database floating, one can only say "somewhere," in cyberspace. Once within, other users are seen as liquid figures moving along the ramps of the spiral. Helped by agents curiously like Vanna White, one passes through the color-coded panes of a panel set across the ramp to enter a subcategory of the search, perhaps a geographical one. One arrives finally at a display of the desired building image and its textual support. This is the system's destination data.

Perhaps most interesting about this visualization is the creative acceptance of *noise* and *distortion* in the image. Indeed, the appeal of the exercise is partially dependent upon it. It suggests a strategy of adaptive refinement, of "graceful degradation" in the way the system works, that is more akin to radio operation—especially shortwave radio—than it is to standard computer graphics. Artists are well aware of the role of the forgiving, partially out-of-control medium in producing wonderful accidental qualities that become essential to the work. Rojas's artistry here shares that quality. It remains a challenge to computer hardware designers as well as programmers to create systems that behave generally in this "soft" way, giving users the initiative and the means to "drive" their systems as hard as they choose, with consequences that are visually apparent, nondestructive, and progressive . . . and yet not entirely predictable. (See Plates 7 to 12.)

Clyde Logue, 1990: This visualization of how a sales convention might happen in cyberspace takes the idea of graceful degradation a step further. Although, like all the previous examples, it creates a world that could easily be rendered in full, three-dimensional, virtual reality mode, in this screen-based model we see a number of concurrent and different screen resolutions; information density ($\mathbf{D}^{(2)}$) is thus allowed to vary visibly. Figures of desire emerge from the noise. Cyberspace itself is imagined as a kind of three-dimensional static, images forming and dissolving from and into a deep video snow.

The convention structure first appears as a flock of panels in tight formation. Among these one drifts at will, immersed in a hubbub of voices and faces and products, each one bearing a coded label, each one a manipulable, hypergraphic element, and each class of elements resolving and unresolving as the user changes his degree of attention towards them. (See Plates 13, 14, and 15.)

Gong Szeto, 1990: Inspired by submarine graphics, this scheme shows visualized data as a sort of underwater topography. The attempt is to give form to the idea of "immersion" in data that is implicit in most VR and cyberspace discourse. The concept of a cell is present but somewhat relaxed. The vehicle itself—the cyberspace deck—provides a rich overlay of screens and analytical devices, together with navigational information as to one's location. Interesting is the tilt of the vehicle, indicating a sort of freedom of user motion relative to a more stable landscape, and the treatment of "on-board" video and data windows as semitransparent and rotatable and yet strongly reinforcing the necessary intermediate frame of reference between user and cyberspace. The system is reminiscent of the head-mounted graphics of VR, flight simulators, and real piloting systems now in use. (See Plate 16.)

Daniel Kornberg, 1990: A "cyberspace video store" hardly describes what is proposed here. The model goes one step beyond the rather easy-to-come-by notion that in cyberspace one should be able to find and preview movies (or musical performances) before downloading them, in compressed form of course, for home play. It shows the interior of a hexagonal structure along whose surfaces hundreds of movies, or parts thereof, are continuously playing on myriad screens. These are arranged in the depth dimension according to a user-chosen variable, defaulting to time/age. As at a market, the user collects images like flowers, flowers-become-screens, floating along with him. These screens in turn can be linked to other parts of structure, and/or other films, chosen for having the same actor, theme, director, location, or writer . . . the possibilities go on. Thus the user becomes a creative force through the act of research and collage, effecting a unique passage not only through the cyberspace structure as such, but through the passages and places depicted in the films themselves. And he need never download. This browsing, this "shopping," may well *be* the destination experience (and we are reminded of the fine line between shopping and consuming in general when it comes to information). (See Plate 17.)

By Way of Conclusion

How tempting it would be to claim that the two parts of this chapter correspond to the distinction Theory/Practice. In fact, both parts are Theory—some might say speculation. It will be some time before anyone can write a section fully deserving of the name Practice.

And yet, I hope to have shown at least how extending the logic of graphic user interfaces into truly three-dimensional realms might be accomplished, and how we might begin to organize consensual and public worlds out of the vast networking power of today's and tomorrow's computers and electronic media. To help make progress in these directions one does not need to be an advocate of cyberspace as such, with its attendant cultural imagery, nor of virtual reality technology with its current promises and rhetoric. My hope is that there is sufficient material in what I have presented— from the observations and suggestions I have elevated to the status of principles, to the impressionistic descriptions and visualizations I have shown as possible outcomes— to contribute to the continuing evolution and speciation of our information-age culture though the computer.

I have tried not to be too partial toward, say, abstract, commercial, scientific or generally academic applications of cyberspace, but there are those, I think, who will find my treatment of persons—personae— and of what virtual worlds offer by way of self-portrayal and interpersonal communication, somewhat lacking. I have not given the full treatment one could to the science and art of telepresence and the usefulness of this technique for experiencing staged or ordinary, if remote, worlds directly (such as "going" to Mars through a telepresence-equipped robot connected to a VR console at home). I have largely ignored the technical difficulties in actually programming and implementing what I have recommended. And I have been rather sanguine about the possibly less-than-salutary political and economic effects of a fully deployed cyberspace.[78]

What can I say?

It is traditional to end a scientific paper with a list of acknowledged shortcomings followed by a statement of how essential further work will be to addressing the issues raised and to resolving remaining difficulties.

Consider the tradition upheld, but, with our topic, and my efforts, more so.

Acknowledgments

I would like to thank my colleagues David Emory Campbell, Larry Doll, Don Fussell, Marcos Novak, and Robert Swaffar for their readings and for the valuable conversations we had while I was writing this chapter, all my "cyberspace students" at The University of Texas at Austin for challenging me to be clear and for their creative and critical input over the last two-and-a-half years, and all the participants of The First Conference on Cyberspace for their confidence, inspiration, and energy. Special thanks are due to Bob Prior, a courageous acquisitions editor indeed, and to my wife, Amélie Frost Benedikt, for making the paper readable at all.

Notes

1. Indeed, the economy of material *property,* which is inherently spatial and which dominates the classical economic theory, in cyberspace is subsumed by the economy of *information,* and with it the idea of *time* as the only true scarce resource. The economy of *capital* is seen as a stage in this subsumption.

2. For an account of the change being wrought in our society by the "informating" process, see Zuboff 1989. There is hardly a problem mentioned in this book to which cyberspace is not the solution. For a discussion of the quality of *realness,* see Benedikt 1987.

3. Gibson 1982, 1984, 1987, 1988; Brunner 1975; Vinge 1987. See also *The Mississippi Review* 47/48, (vol. 16, numbers 2 & 3, 1988); *Mondo 2000* #2 , Summer 1990, whole issue *Metropolis,* Sept. 1990, pp. 40ff; *Whole Earth Review,* Fall 1989, pp. 108ff., and *Smithsonian,* vol. 21, #10, January 1991, pp. 36ff.

4. What George Gilder (1989) calls *microcosm.*

5. And we must often be tightly swaddled to ease the shock.

6. On the matter of principles: many would leave unanswered the question of which of the two—the felt, somehow-known-as-unitary *phenomenon,* or the set of operable *principles*—has the deeper, more originary status. In practice, some are guided by a sense or vision of the phenomenon itself, even as they investigate and encode it by rules and principles, while others are guided by the play of rules and principles among themselves and their unwinding interaction in long, symbolic chains, without visualization of what, as a whole, these rules and principles together constitute or signify. At best, such wholenesses are intuited.

Certainly it is the skill to work in this second way that has allowed mathematicians to develop many exceedingly complex theorems in topology, algebraic topology, and functional analysis that may involve many more than three dimensions and/or deal with manifolds of complex numbers.

7. I think the case can convincingly be made that religion in the form of a church/temple was historically the first information business, and that the coordinated space of gods, the sites of their interplay, and the world of sacred texts, images, accounts, and accountings sustained by religions since time immemorial, constitute the forerunners of cyberspace. Much that was done, and of what simply happened, in the real world of ordinary things and ordinary people was seen as the direct result of goings-on in this sacred virtual world, access to which by mortals was limited to shamans, priests, heroes, and the dead. (Today we might want to add hackers to this list, or, at least, hackers might want to add hackers to the list.) In any event, there will be room for considerable scholarship someday into what will be seen less as the *invention* than as the *evolution* of virtual worlds into the electronic medium. I hinted at all this in my introduction to this volume.

8. In movies we have "user-uncontrollable" illusions of such; another sort of writing, and another sort of reading on our part.

9. I have always thought that the modern computer screen resembles less a "desktop" than the patch of sidewalk used by a street-corner conjurer.

10. Though clearly one should design the former to suit the latter. This observation was also at the heart of widespread objection to the co-option by Autodesk Inc. of William Gibson's word "cyberspace" as a trademark for their VR interface system with AutoCad. See Sterling 1990.

11. Part of this has to be cultural, of course. Hebrew is written right to left, Chinese top to bottom, and so on. But within these cultures, top is "elevated" over bottom and center over margin, always. I expect that all systems of literacy using a *field* of inscription or markings to record information—be it a stone block, the wall of a cave, or the side of a building—vivify that field with polarities and values thought of as *belonging* to the field more or less intrinsically.

12. It is probably best not to think about the task in these grandiose terms too often however . . . except to notice how every development in computer technology, from chips to monitors, from connectivity to games, every step that moves towards realizing this essential, if unstated, vision is greeted with such unreasonable enthusiasm. Examine the hype, examine the names chosen for companies and products: the entire computer industry, it can be argued, is drawn along at maximal velocity by the fantasy of virtual realities such as cyberspace, even as it is currently sustained by the enormous profits to be made in the rather dull business of processing business and scientific data and computerizing the second and third worlds.

And there is this complementary movement: a nostalgia for working with our hands, for being craftsmen, for honest, real labor. Cyberspace, in the way it reifies information and operations on information, offers symbol workers—from executives and academics—feeling guilty in some way that their work is abstract and invisible, intangible, and yet highly paid and displacing of their fathers' more "honest" labors, a return to or recovery of the procedures associated with tangible things and with visible creation. On this theme, see Zuboff 1989.

13. To think of the dimension of *time* as equivalent to a dimension of space and therefore of reality as profoundly and somehow symmetrically four-dimensional is less easy, even though a library of books has been written about the nature of this "equivalence" and the superior scientific status of the four-dimensional space-time world description. I expect that the reader, like myself, has read no small part of that library!

14. I am assuming that we can always deal with 4-space by constructing a model in 3-space that changes over time.

15. In the language of algebraic topology, a point can also be *open* or *closed*.

16. Rather than "phase space." Phase spaces are always conceived of as n-dimensional. The whole state of a system is thus described by one mathematical point in the phase space. What physicists are apt to call "phase space," mathematicians will often call "measure space," econometricians and engineers, "state space," and so on. To my mind "data space" is the most generic and inclusive term for these and other representations such as matrixes and "spreadsheets," and will lead most easily on to the notion of cyberspace as a kind of superrealm of living, breathing data spaces with which you can interact.

17. I like "intrinsic" and "extrinsic" rather than the terms "internal" and "external" because the last pair of terms—especially "external"—too easily leads one to think of the "outside" shape and size of the object as such rather than its spatiotemporal location and kinetic behavior, which is what I mean by "extrinsic."

18. So named because of the similar postulate in quantum mechanics called the Pauli Exclusion Principle. This states that no two electrons (or fermions) belonging to the same atom can have the same quantum numbers. This simple restriction on an "object" generally regarded as a point spatially, combined with the basic level structure of quantum theory, is responsible for the structure of the periodical table, the nature of chemical bonding, and most of the properties of matter including the macroscopic exclusion principle referred to here. (Citation from Cooper 1970, p. 395.)

Pauli's principle is weaker, however, not only because it applies to electrons in one atom only, but also because it excludes two "objects" only from having the same value on all dimensions, only some of which are spatiotemporal. For example, two electrons can have the same momentum and level as long as they have different (opposite) "spin." Our exclusion principle says that intrinsic nonidenticality forbids extrinsic (spatiotemporal) identicality, while intrinsic identicality and extrinsic identicality devolves to the simpler case of self-identity or singularity.

19. I am aware that this is not the definition of the term "self-similarity" today.

20. Indeed, a "field" in mathematical physics is broadly defined as a function, g, in which every point, extrinsically specified, has a mapping to an intrinsic value or values of some quantity: $F = F_{x,y,z,t} = g(x, y, z, t)$. F may be scalar (single value) or vector (two-value), or tensor (matrixed multivalue).

21. The reader may be getting jumpy at my presumption at this point, but let us remember the presumption implicit in being Creators of cyberspace in the first place.

22. This is why hyperdimensional grand unified theories (GUTs) in physics, such as supergravity and superstrings seem illegitimate to the true atomist. Coiling or twisting or otherwise packing all the world's remaining fundamental physical dimensions (there are apparently 7 more) into tiny regions of regular space-time, it seems to the atomist, is a little too easy, a sort of sweeping of the problem into the rug. "Have problem? Hitch another dimension to space-time. But better make it intrinsic, that is, invisible and/or non-space-consuming; otherwise we'll have to explain where it went, why it isn't out here. And if this intrinsic dimension *must* be spatial (after all, in this trend towards the geometrization of nature we don't want to end up with anything like Cartesian *stuff* with inherent character) then coil it up in an inaccessibly small labyrinth at the heart of the tiniest 'particle.'"

I am being flip here, of course. But in essence this seems to be the situation. Viewing nature's doings ultimately as geometry, as a "condition of space-time," may be a worthy goal (it is the true atomist's goal at that), but having then to conceive of seven such "spatial" dimensions not acting spatially—not "out here"—but locked up in uncountable microcosms is surely forcing the meaning of the word "spatial." This in turn leads to interpreting the fact that many behaviors of particles lend themselves to visualization in geometrical formalizations—indeed, in data spaces—as *proof* that such spaces exist in physical fact. (Of course, thinking of intrinsic dimensions as spatial, and representing them this way as an aid to visualization, is perfectly legitimate.) The universe may indeed be "eleven dimensional" at root, but either only three are space and one is time, or we need a darned good explanation of how and why the other seven got kidnapped.

I am not the first to wonder about this, by far. Popular expositions of this territory are legion. This comes from Davies 1984 (p. 162):

"In their search for a reason why seven dimensions should spontaneously compact themselves, theorists have been working on the assumption that physical systems always tend to seek out their lowest energy state. . . . This suggests that a shrunken squashed seven sphere is in some sense the lowest energy configuration of space-time."

Perhaps. I suggest that it may be an informational matter, that intrinsic dimensions (if they exist at all physically) are utterly nonspatial, and that all the whole phenomenon is the work of the Principle of Maximal Exclusion. This interpretation makes sense of the surprising mathematical fact, for example, that *only* 4-dimensional space-time (not 3, or 5, or 6 . . .) allows for an uncountable infinity of differentiable structures in mathematics and stable orbits—among other phenomena—in physics. Cf. Stewart 1987 and Barrow and Tipler 1987 (pp. 258–276).

23. The evolution and exploration of cyberspace will shine light not only on the questions of physics but on the meanings of "evolution" and "exploration." Fundamental connections between cyberspace and reality may only become understood as, perhaps, they draw parallel in the far distant future. Until then, they are best thought of as separate.

24. It also tells us why the world seems to consist of persisting objects and field types in spatiotemporal "motion": space-time is the largest container, informationally speaking, for the "complexification" of the world to "take place" at maximum "extension." (Extension: the classical word for *space*, used by Descartes, Spinoza, Leibniz, and their contemporaries.)

25. For a comparable set of ideas, cf. Barbour 1989. Barbour employs a graph-theoretic connectedness measure of identity such that the "distance" between two vertices is a measure of the difference in their connectedness. Maximal variety is the principle whereby the number of distances in a network is maximized. The suggestion is that just such a mechanism can "cause" space-time.

26. It is appropriate to make further note now of some of the similarities and dissimilarities between the formulation offered here and that of the notion of *phase space* in physics and scientific visualization.

In classical physics, the state of a system consisting of **n** unconstrained particles—each particle with a position (3 dimensions), and a momentum (another 3 dimensions)—can be represented as a point in a phase space of 6**n** dimensions. The evolution of a system is described by the Hamiltonian equations and can be visualized as the trajectory of the point through phase space.

Notice that, in our terms, all the dimensions are here treated as extrinsic; the idea of the "point" is thus saved, as it were, from being nonmathematical, that is, from having any quality or character other than pure existence. The idea of a point in phase space goes atomism one better: the state entire universe can be represented as a single point! The fact that no one can actually visualize a space of more than 4 dimensions—much less a phase space several thousand dimensions that even a simple, atomically considered real system would generate—is regarded philosophically: that is, as sad, but true. Nevertheless, several ideas and several theorems can be elegantly represented with the idea of phase space. One such example is Joseph Liouville's deduction that the volume of phase space occupied by Hamiltonian-governed systems must be preserved over time.

In phase space, the Principle of Maximal Exclusion does not apply, and this by default. Why so? Because in phase spaces—for all their similarity to data spaces—the complete state of a system is imagined contracted to, and coded as, a true point's simple position in a reference frame. There is no possibility that *one* entire system can, at the same time, be in *two* states. Of course, if there is uncertainty as to the state of the system, one may proliferate points and attach to each a probability of being the case. Alternatively, one may map and regard simultaneously all the possible states of the systems, thus viewing the behavior of the system as itself a system (in phase space). In both of these cases PME might indeed apply if interpreted as a "desire" of the system to differentiate its possible states, to wander ever further and in more complex ways through its phase space. Indeed this is the character of so-called ergodic systems and chaotic systems, but I am unclear as to how to make firmer claims that I can only intuit for PME in this context.

For us, PME only becomes useful—operative—when partitionings are being made between extrinsic and intrinsic dimensions.

If phase space casts all dimensions as extrinsic and if, because of this, it is difficult to visualize complex or highly populated systems in full or accurately, then phase space's logical opposite (which I will call briefly *h-space* for no good reason) is slightly less of a problem. For in h-space all of a system's dimensions would be regarded as intrinsic, and only one or two, extrinsic. (Having *no* extrinsic dimensions seems to defy existence, *pace* Kant). The situation is one we can visualize more easily. It would consist of arbitrarily small and complex objects in a 1- or 2-space such that the position of the objects, their trajectories, and geometrical interrelationships made no difference and meant nothing. PME would similarly have no meaning. In fact, the spatiality of such a space would be largely gratuitous.

(Phase space is a common notion in physics, both classical and quantum [where it is called Hilbert space after the mathematician David Hilbert]. For a recent and illuminating rendition for the nonspecialist, cf. Penrose 1989 (pp. 176ff.).

27. Stereo sound is, of course, the easiest extra channel of information to add to the purely visual cyberspace we are designing. It may well be a crucially important one, as may well be voice communication. However, this chapter will deal with the opportunities and problems of sound no more than tangentially. I will not specifically refer to hardware and software technology again until the second part of the chapter.

28. It is likely, for example, that the sound of an object is the most suitable medium for carrying large amounts of intrinsic data rather than sight. In the real world, the sounds of things—noise, music, voice—seem to issue from within them and express their character without affecting their look or spatial behavior. Thus sound seems to be a natural model for carrying intrinsic data of all sorts, as I remarked earlier.

Take the "cybercube" of the previous paragraph. We could easily hear its faces quivering, and even its pattern of tumbling.

Another approach is to use our natural ability to decode certain complex social stimuli such as facial expressions. The shape and condition of facial features, for example, can be made to reflect the simultaneous values on a large number of dimensions, having, of course, nothing to do with faces. These would be its intrinsic dimensions, the place of the face as a whole—or its address point—being its extrinsic dimensions. See Chernoff 1973.

29. Cf. the work of Ken Perlin, Department of Computer Science, Columbia University, on "fractal windows." "Scratch and Pad Demo," videotape, 1990.

30. This in essence was the way the visualization of a hypercube was achieved in the 1970s by a number of researchers. See papers by David W. Brisson, A. Michael Noll, and Thomas F. Banchoff and Charles M. Strauss, in Brisson 1978.

31. Of course, at a lower level this happens necessarily as the computer itself computes which view of a stable non-self-transforming object to put up on the screen every *n*th of a second.

32. Actually there is still some "graphic redundancy," or overdetermination, in this visualization. Only two surfaces are needed to locate a point in 3-space, that is, one pair from the set {(x,y), (x,z), (y,z)}. It is possible therefore not to need to unfold a *second* space but to choose complementary pairs of "walls" to locate data points in the *same* space (phenomenally speaking). For example, in this figure, **p** in XYZ could be located by the left "wall" and the "floor," and **p** in ABC by the "back" and the right walls. Thus the behavior of a line segment can represent the action of 6 variables, while in theory, if we bring the "ceiling" and "proscenium wall" into play, the behavior of a triangle in a single phenomenal "room" can represent the action of a 9-dimensional system. Now add color to the triangle's surface . . .

The reader will also realize that the unfolding of intrinsic dimensions into subspaces can go on indefinitely. The possibility of *circularity* also presents itself, that is, where the third or fourth unfolding, for instance, unfolds to the first "mother" or matrix coordinate system!

33. I say *almost* completely because the user can arrange his icons in the window to reflect some of their properties in their position—for example, recency and size—and it is conceivable that the computer can do this for the user intelligently; and certainly there are already implicit rules one can follow having to do with the Western tradition of how text belongs on a page such that the top and left of a page are privileged over the bottom and right, the center over the margins, and so on. See also the chapter by Alan Wexelblat in this volume.

Of course the undifferentiatedness of the space of "windows" is part of their usefulness: they are very forgiving. Like real space you can put things/icons more or less anywhere in a "window" and the window almost anywhere you please on the screen (and the computer almost anywhere you please in the room, and yourself almost anywhere you please in front of the screen . . .).

34. One small example of the further options that appear with this notion, and using not only extrinsic but intrinsic dimensions as controls: an object may not

bloom unless it has been rotated into a certain position . . . or moved, or has turned to a certain color . . . thus making certain states prerequisite to others.

35. Cf. Chris Isham, "Quantum Gravity," in Davies 1989.

36. Praise for the alphabet as an invention too often focuses on the fact that is a limited set of symbols of tremendous combinatory power, and not frequently enough on what a universal precedency system the absolutely tight *order* of the alphabet provides together with the gift of naming . . .

37. For a very accessible treatment of this, see Abraham and Shaw 1982–1988.

38. Strictly speaking this axis is not continuous but has a "Plank length," or quantum, of one cent.

39. The technique is not dissimilar to standard data compression techniques, especially for graphics.

40. Ways to finesse the ancient, concomitant dilemma of how *any* number of sizeless things can amount to something of finite size remain problematic for most of us. Typically we simply declare that there is as much space in any defined space as the volume measure, V, of that defined space indicates, measured in the metric of the coordinates of that space.

41. It will also shrink and expand in **space**$_u$. In fact, any two-or-more pixel particle could exhibit all the laws of refraction, where D is akin to the refractive index, and of gravitation, where D is a dual of mass density.

42. Actually this point is debatable, especially if one follows Edward Fredkin (see Wright 1988).

43. The reader may wonder how it is that we *know* that we have slowed, embedded as we are in **space**$_o$, unless we also have access in some sense to an inertial **space**$_u$ relative to which we have truly slowed. To expound on this fully would be to attempt to explain the phenomenology of General Relativity, a task in analogizing that I leave for the future. I hope it suffices here to suggest that (1) indeed, we have no way to sense acceleration noninertially except by the variability of the size of space around us, and (2) we make the continuous assertion that space$_o$ is uniform, at the current value, everywhere, that is, time is the constant metric, and $d\mathrm{D}3/dt$ is the variable of phenomenological import.

44. But in reverse of course. Light bends around a star not because of curvature, but because of the rarefaction of space-time, a lowering of $\mathrm{D}^{(4)}$, in the region of the star. Perhaps gravity—natural "attractive" gravity—is nothing more or less than the "simplicity in things". . . calling to each other. What makes black holes so very attractive, then, is their extreme, and total simplicity. (Notice the tie back to PME here.) But this is to take perhaps too seriously the notion of the real world as an *information field, and information as the ultimate substance of the universe.* At any rate, the idea is deeply relevant to cyberspace since cyberspace is explicitly, and by design, nothing other than a field of information (and very crude compared to physical nature). The fruitfulness of the comparison to me must by now be quite evident to the reader of these last footnotes.

45. Essentially screen size in pixels or "physical closeness in cyberspace," measured in steradians.

46. See Bergman et al. 1986. There is also the well-known strategy of selective or adaptive detail rendering as a function of gaze direction, and techniques such as Incremental Radiosity, where only changed or new objects in a scene are calculated.

47. The equation "reality generates consensus" has its converse too: "consensus generates reality." To some extent, the same can be said of the phrase "reality generates science . . ." To go much further with these statements is to embark on a debate that has been one of the major themes of philosophy, art, and science, East and West, for thousands of years. . . .

48. The lesson has yet to be fully learned by most arcade video-game designers. On the Principle of Indifference (and on this corollary of it, the Principle of Life Goes On) the game should go on even without the player. The situation in the machine should develop with play, of course. But any one player's situation may deteriorate simply out of his neglect to play. Things may be taken "behind his back," overnight. Messages may await him. As in real life, he must return: return to fight against others, to influence the World that will be others' to deal with, and just to fight against entropy and aging. (There are a few text-based PC and Mac adventure games that have the capability of changing the situation if you think too long—the situation usually changing to your disadvantage. Also, most arcade games keep a record of top scorers' initials. This list can change in your absence.)

One might reasonably have moral qualms here. The Principle of Indifference, in the form of "Life Goes On," will make addicts of all of us! Another name for the principle? The Principle of Mortality.

49. This, I fear, is the implicit promise of today's virtual reality technology, even though VR's proponents have loftier goals. One cannot but be aware of the psychedelic cast Timothy Leary and others have put upon the area of VR.

Now, being a "child of the sixties" as they say, I personally do not wholly disapprove of the psychedelic project. But cyberspace, if it is to be a public and democratic realm, will have to seek consensus as to what is privately mutable and what is not, similar perhaps to the kinds of social restrictions placed on real-space architects and public-space sculptors and muralists. As an architect, I dread *this* possibility taken too far also (zoning and aesthetics committees in cyberspace?—please, no!), but it must be realized that without true physics, nature, evolution, or tradition, without clients, economics, or others with other*ness*, without even a necessary landscape such as a horizon and such as verticality and some definition of territory and address as backdrop, the alternative will be a chaos of images useless to everybody. In fact, cyberspace might not even get "off the ground."

50. It would seem at first that the ultimate intransigence/nonmalleability on the part of a computer system is its sometime "refusal" to do the user's bidding: after all, this is the system being independent, saying no, saying "I am what I am."

However, with ordinary reality there is always something that can be done: the "natural system" never really *freezes*—as computers often do—and, so far, the natural system never completely *crashes*—which computers sometimes do. Thus, holding to the Principle of Indifference does not entail advocating these ultimate intransigencies for cyberspace. Cyberspace entities and locales ought to remain responsive to manipulation and navigation always, even if truncated by equipment failure, user malevolence, or user ignorance. In fact, the ability to freeze or crash the whole or part of a cyberspace system deliberately, or even by mistake, is an indication of the system's relative fragility and therefore unreality. You cannot break what is indifferent to you.

One implication of all this is the nonadvisability of having cyberspace be located or controlled centrally, or its communication links constrained only to one "system of wires," say ISDN. Rather, cyberspace processing should be distributed, and its communication channels many and alternative: phone lines, satellite, HDTV cables, even radio and power lines. The technical aspects of all of this are daunting: we have not really begun to solve the problems of distributed databases and distributed processing on the scale required by cyberspace. And, of course, there are myriad political, economic, and power-related questions involved in this notion of decentralization and redundancy . . .

51. For a beginning compendium, see Rasmussen 1959, Harbison 1977, Nitschke 1966.

52. For example: as far as I know, another strategy is that of software-based, user-controlled differential or *multiple resolution* on a given screen, not implemented but as illustrated in Part Two of this chapter—that is, the arrangement whereby a particular data object or set of objects is assigned a display resolution different to others, and different to the background.

53. The loss of light energy by the inverse square law is inconsequential; our observers have indefinitely sensitive light detectors, let us say.

54. This is an approximation that breaks down slightly when r, the radius of the disc, is comparable to r, the distance to the observer.

55. Benedikt 1979, Benedikt and Davis 1979. ISOVIST, a computer program written for the Unix OS and SunView, available from the author and The University of Texas at Austin.

56. See my "The Information Field: A Theoretical and Empirical Approach to the Distribution of Information in the Physical Environment " M. E. D. Master's Thesis, Yale University School of Architecture, 1975. See also Koenderink and van Doorn 1975, 1976.

57. Throughout this chapter, it has been taken for granted that just as data exists visually, aurally, in cyberspace, so do its *users* for each other. There is much to be discussed here about the nature of personal presences in cyberspace. Cf., for example, Stone (this volume).

58. Mark Heyer provides the following taxonomy of increasing engagment with information: *grazing, browsing,* and *hunting*. Cited by Brand (1987, p. 43). In my teaching I like to expand the taxonomy thus: *soaking, browsing, watching, hunting, fetching/getting, making*. Only cyberspace is able to provide a suitably rich and indifferent environment for the first four stages, and perhaps the sixth. If one only wishes to *fetch* or *get* information, whose type and location one knows, one does

not need cyberspace, nor, for that matter, any GUI. With a connection to Internet and an FTP (File Transfer Program) on your own machine, for example, you need only to know the Internet address of the host machine, the name of the file, and perhaps a password. On request, the information in that file will simply pour onto the screen (or into your computer's memory). The file is pure destination data; navigation data is minimal, or rather, is maximally compressed and encoded into a string of digits and characters, absolutely critically ordered. With requests for user and file directory information—word lists—a certain amount of *hunting* can be done this way also. See Stoll 1989 for a hacker's account.

59. It should not be overlooked that the dollar-cost of travel to users may be one of the economic engines that drives cyberspace as a money-making enterprise (no matter who "runs" it or parts of it). Other sources of income to the owners and maintainers of the system are easy to see: outright purchase of real estate in cyberspace, the leasing of such, advertising time and space, connect-time charges to the system and to individual presences, innumerable hardware purchases and upgrades, cabling systems, satellites and so on, access software, endless enhancements to this, etc.; and all this in addition to the value of the information bought and sold as such within the system.

More broadly, one should note again that *time,* and not spatial/physical property, is the new and salient capital and currency of the "information age." Allocating it, saving it, investing it, buying it, selling it; in minds, in computers, on tape; on line, on air, on screen; at home, at work, in transit . . . We have not yet begun to formulate the new economics of time and information, as I alluded in the introduction to this chapter. It is being invented "on the fly," with sporadic progress reports in *Newsweek* and *USNews.*

60. In analogy: a public hypertext in which every word led to another document or another part of the text would be disorienting and close to useless, unless *tracks* of some sort are laid down and are visible to later users. See Nelson 1990.

61. See Isaac 1980. Glynn Isaac, an anthropologist, reports finding the same pattern in the daily movements (tracked from the air) of a variety of African mammals, including the Bushmen of the Gobi desert. From home base the day is spent searching, tracking, gathering items here and there. When the goal is reached (an animal or enough food) one comes home as directly as possible. Actually, arboreal primates such as chimps and gorillas do not maintain the pattern as strongly since they range through the forests continuously and do not make permanent homes.

62. Conventional usage quite correctly follows the hierarchy: "data"/ "information"/ "knowledge/ "wisdom," and technically I do indeed mean navigation and destination *information.*

63. Instantly, of course, we must remember his slogan too: the medium *is* the message (actually he liked to say *massage*). Be this as it may, the distinction between navigation and destination data holds up to all but the most determined post-structuralist deconstruction, and along these lines: no information does not lead to other information, therefore no information can be a true destination; all information is navigation data and destination both, and neither, intrinsically, and by the nature of signs. For a more detailed look at this argument, cf. Norris 1982, Benedikt 1991.

64. The possibility also exists, however, for any or certain objects in cyberspace to be under a modicum of [temporary] user control in this regard, as when an object is "asked" to bias its self-presentation to the individual user toward either its navigational or destinational aspects. This would accord well with Fuchs's adaptive refinement, except that here the semantic category and not just the net amount of information processed/displayed is controlled by user intention/attention. More elaborate selective display mechanisms are a possibility too, and in the section following the next we will look at this question again.

65. The problems of communication privacy and security will be no better and no worse in cyberspace than is the case with today's computers and telephones. What can one say here: there will be no "wire tapping"?

66. This is a consideration that at one time I had elevated to a principle in its own right: the Principle of Universal Verticality. Millions of years of life on this planet has ensured this most fundamental of agreements, and as the experience of astronauts testifies, it has become deeply necessary for perception and orientation for there to be a consistent vertical orientation in the environment. More specifically: it seems obvious that insofar as negotiating cyberspace will involve perceiving symbols, pictures, people, faces, texts, and so on, that it would do no good for them to appear out of nowhere in random "gravitational" orientations. Also, cyberspace as a whole might have gravitationlike valences, different meanings, capabilities, and destinations tied to "altitude" and to vertical motion in the large.

67. Abstract commonality as in ". . . you and I have a lot in common: we're both from Minnesota, have red hair, like guava . . ." is not intended here.

68. The property of no pair of sets having more than one disjoint intersection can define the meaning of set *convexity*.

69. This passage from *The Lion, the Witch, and the Wardrobe*, and by way of interlude, captures it all. From C. S. Lewis 1950, (pp. 5, 6, 7):

> Everyone agreed (that) this . . . was how adventures began. It was the sort of house you never seem to come to the end of, and it was full of unexpected places.
>
> (After looking into many rooms) they looked into one that was quite empty except for one big wardrobe; the sort that had a looking glass in the door. To (Lucy's) surprise, it opened quite easily . . . She immediately stepped into the wardrobe and got in among the coats and rubbed her face against them, leaving the door open, of course, because she knew that it is very foolish to shut oneself in any wardrobe. Soon she went further in and found that there was a second row of coats hanging up behind the first one. It was almost quite dark in there and she kept her arms stretched out in front of her so as not to bump her face into the back of the wardrobe. She took a further step in, then two or three steps . . . pushing the soft folds of the coats crunching under her feet . . .
>
> (It) was soft and powdery and extremely cold. "This is very queer," she said, and went a step or two further. Next moment she found that what was rubbing against her face and hands was no longer soft fur but something rough and even prickly. "Why, it is just like branches if trees!" exclaimed Lucy. And then she saw that there was a light ahead of her; not a few inches away where the back of the wardrobe ought to have been, but a long way off. Something cold and soft was falling on her. A moment later she found she was standing in the middle of a wood at nighttime with snow under her feet and snowflakes falling through the air.

. . . "I can always get back if anything goes wrong," thought Lucy. She began to walk forward, crunch-crunch, over the snow and through the wood towards the other light.

One might as easily have chosen a passage from Lewis Carroll's *Alice in Wonderland* or *Alice through the Looking Glass,* or the myth of Orpheus and the Underworld.

70. This is a technology currently under development by the author and cannot be divulged until patenting is secured.

71. The reader may enjoy interpreting the behavior of lovers in terms of the strategies (1) to (4) just outlined.

72. Cf. Markoff 1990 for a nontechnical overview of the national effort.

73. A symbolic cyberspace based on the symbolic space of literature, as it were, was mentioned earlier; namely, TinyMud, the interactive, text-based, networked, city-metaphored venue for hundreds of participants that functioned in 1989 and 1990 out of Carnegie Mellon University. ("MUD" is an acronym for Multi-User Dungeon). More graphic was/is Lucasfilm's Habitat of 1985, also based on the model of the city, which ran on the Commodore 64 computer. (See the chapter by Morningstar and Farmer, this volume). Both systems created consistent imaginary environments for hundreds of concurrent participants through rather simple means, computationally speaking. Although both were essentially entertainments, there is no reason why good amounts of useful information could not have been located, accessed, and manipulated within the structure of their imagined, and therefore doubly unreal, cyberspaces.

TinyMUD has spawned many "MUDs" since, most of them running out of university workstations, for example, at the time of writing: Islandia (Carnegie Mellon), Club Mud (U. of Washington), Chaos (U. of Oklahoma) TroyMUCK (Rennselaer Polytechnic), Pegasus (U. of Iowa) Mbongo (U. of Calif. at San Diego); and many more. See the newsgroup *alt.mud* on the USENET for updates.

74. The room is also equipped with slide viewing racks, that is, large rear-illuminated, sloping panels with horizontal tracks to arrange slides upon. Certain mechanical actions are demanded: physically opening the drawers, reading labels, holding slides up to the light for preliminary viewing, taking them over to and setting them upon the viewers without dropping them, leaving behind special markers, mounting the slides in projection trays, etc. . . . these cumbersome and time-consuming activities would easily be superceded by any computerized optical disc storage and retrieval equipment. But we are here more interested in the data itself and its spatial organization.

75. There could reasonably be a clean division here between *exterior* and *interior,* and a further one between *day* and *night* views. These could be disposed linearly within the dominant dimension, or with enough images, could become orthogonal dimensions in themselves.

76. One has the opportunity here to encode two independent values instead of one—that is, one for left-of-centerline ribbon width, one for right-of-centerline width, like the grooves on a stereophonic vinyl record; and yet another dimension or two is available if the *color* of the ribbon is varied and encoded. These options were not pursued.

The reader may also have noticed that, since there are two plane surfaces per orientation in a real room (floor and ceiling, left and right walls, fore and aft walls), *two* points in a cell, perhaps with a line joining them, can represent *six* dimensions at once. Each point's position is referred to, and governed by, a different set of three walls. In fact, four walls—two *pairs*— are sufficient for six dimensions because of the redundancy inherent in the partition X-Y, X-Z, Y-Z.

77. One alternative is for neighboring cells to be dark, empty—perhaps just rendered in outline—if they are "broken into" from the side. If the new cell were also transparent, one would thus find oneself in an immense, largely empty, cubic framework, stretching to infinity. If the cells are partially "content-full," and translucent, however, one would find oneself embedded in a universe of deeply overlayed images. Assuming sufficient rendering and computing power, the second option could be most pleasant and stimulating. But lost would be the navigational data available and inherent in the *over*view and the *over*flight scheme that I am suggesting should be, if not necessary, then the norm.

78. After all, William Gibson was portraying a future he did not and does not condone—indeed, one that he dreads—even as he was relishing its narrative potential. We can expect his future books to make this clearer.

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