# ***THE INFORMATION IN SPACE IS THE SPACE IN INFORMATION***

by

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In this short and I hope not-too-technical paper, I shall attempt to outline some of the implications—for our understanding of space, time, and consciousness—of recent advances in data visualization and communications using computers. As an architect, I shall concentrate on space. I shall begin with an overview of concepts of space and then offer three thought experiments, all three with the objective of showing that the idea of information, of "data," already contains the idea of space within it and vice versa: that there seems to be space in this world at all, even "physical space," is because the world produces information, indeed *is* information.. I conclude with remarks addressed to the virtual worlds creatable today by electonic media, remote sensing, and cyberspace technologies.

## Space, in Historical Perspective

Positive space, negative space, Baroque space, Modern space, urban space, domestic space, architectural space, urban space, pictorial space, abstract space, inner space and outer space, secular and sacred space, phase space, parameter space, color space, psychological space, auditory, tactile, personal, social space, now polar space…what exactly are the adjectives qualifying? What is space itself? No one knows. The problem has vexed philosophers since Plato. A quick review is instructive.

For Plato, space was the totality of geometric relations possible, i.e. the totality of numerical facts applicable to distances and directions. For Plato space was filled, as it were, with a dense web of gossamer strings drawn from every point to every point, some resonating over the white noise of all them like chords plucked on a harp. Hence the attention to *proportion* that characterizes classical architecture to this day, as well as the link that still exists between *ratio* as a comparison of two quantities and *ratio-* as the prefix to words denoting reason itself.

For Aristotle, space was nothing other than *place*, or the generalized sum and place of all places. If Plato's definition was geometrical, Aristotle's was more topological: (the) place (of something), he said, was the inner surface of the first, stable, environing container. The place of a chair is the room it is in, the place of a river is the river bed it runs in, the place of

the moon is the next-outward celestial sphere. For Aristotle, space was the resting surround, or most abstractly, surroundingness itself.

The Medieval period saw these views co-mingled. But a new and spiritual element was added. Space was light, radiance, Spirit, or God Himself. Radiant, infinite, immanent, permanent, incorporeal..are these attributes shared with God?

By the time Descartes put his mind to the problem, space *per se* had become an impossibly mystical notion. Descartes brought back to it a dynamic and mechanical aspect. In classifying space and everything physical as "Extension," and by opposing this to "Thought," Descartes reasoned that space was simply *that which permitted* mechanical motion. One atom impinged upon the other atom directly, like so many ball bearings but without any empty space between them. Vacuum, void, was impossible; space was full of atoms-in-contact. Rather than specify what space *is*, he specified what it *does*, namely: space allows motion.

Dissatisfied with only mechanical terms, Leibniz was to extend this kind of operational definition further. Space, he argued, was that which permitted not only atoms and motion but the very existence of *identity* and *simultaneity* as such. Without space, he said, "things" could be neither unique nor countable. Everything would be collapsed to a single "point," to one thing, which is to say, to no-thing, since there would be no room for another thing to distinguish itself from the first. Moreover, in order to introduce change, such as motion, and in order for there to be *more* than one object in motion, not only simultaneity but also an object-identity-that-survives-motion is required so that the motion can be said to have happened at all. With his principle of the Identity of Indiscernibles—as this doctrine is called, and which we will discuss presently—Leibniz probably came closest to what we could call an information-theoretical view of space.

Newton, for his part, thought of space as pure vacuum, Absolute and unmoved, a plenum of nothing but positions--points--continuous and empty in every direction. This view remained largely intact for a hundred years. But by the Twentieth Century, space could no longer be thought of without *time*. After Einstein in particular, the project enlarged to understand space-time as the four-dimensional, fundamental "unified field" providing both the totality of all cosmic frames of reference in relative motion as well as the “substance” of reality itself as the ultimate weaving of light with gravity.

Now, the physicists' and philosophers' idea of space-time was to have enormous impact on artists and architects of the twentieth century, as we know. We also know that this impact had little to do with what Einstein was getting at with his theories of relativity.[1] Rather, space-time and "relativity" were taken as invitations to investigate the extremes of openness, "multi-perspectivalism," dematerialization, and mobility as worthwhile aims for the design of buildings and cities. To this very day, surveys report that the textbook thought by architecture teachers to be the most important for students to read is Siegfried Gideon's 1941 *Space, Time, and Architecture,* surely one of academe's most mistaken explications of Einstein's ideas.

It is quite beyond the scope of this article to rehearse the concepts of space as propounded by architects and architectural scholars during this long history, except to note that it was not until the 1750s that the notion arose that space as such had anything to do with

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[1] See Linda Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton University Press, 1983).

architecture,[2] and that it was not until the twentieth century that the idea caught on that what architecture *primarily* did was "shape space." Consider these passages:

**...though we may overlook it, space affects us and can control our spirit; and a large part of the pleasure we obtain from architecture…springs from space. The architect models in space as a sculptor in clay.** (Geoffrey Scott, 1915)

**Space and Time are reborn to us today. Space and time are the only forms on which life is built and hence art must be constructed. (Antoine Pevsner, 1920)**

**…the new reality that is space instead of matter.** (Frank Lloyd Wright, 1943)

**To get a hold of space, to know how to see it, is the key to understanding buildings.** (Bruno Zevi, 1957)

**(This) is easier for architects because they are used to dealing with the slippery impalpable stuff.** (Sinclair Gauldie, 1969)

**(Walls) tightly stretched by the pressure of the continuously open spaces inside them... (T)he interior space, maternally rounded and swelling...** (Vincent Scully Jr., 1961)

**It only becomes possible to perceive and experience space when it is enclosed by architectural forms.** (Miles Danby, 1963)

In the writing of architect-planners—from Camillo Sitte in the 1890s to Rob Krier in the 1980s—these same ideas abound: streets and plazas are outdoor rooms; their shaping "control(s) our spirit." Far from exempt, the American highway and gridiron city, the skyscraper and strip, were seen as simply another *kind* of space. As early as 1908, Hendrik Berlage, scorning nostalgia for the picturesque space of the European street, square, and plaza wrote: "Feeling for space: only those equipped with that feeling can understand the beauty of the American city." And most recently, under the impact of postmodern realities, theorists have pushed beyond the essentially aesthetic discourse that has preoccupied architects. "Space is political and ideological," proclaimed philosopher Henri Lefebvre, inspiration of many architect-planners today. "It is a product. It is a product filled with ideologies."[3]

Oh, what a load "space" must carry! Every responsibility devolves upon it: from supporting the innocent play of geometry to being answerable for our well-being, from providing the ground of physical reality to accounting for political and economic evolution. Clearly there is more being asked of the concept of space than space alone—so empty, so shy—could possibly provide. Indeed, as we look over this sample of what modern architects

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[2] This according to Peter Collins' *Changing Ideals in Modern Architecture, 1759--1950* (McGill Univ. Press, 1965).

[3] Henri Lefebvre, *The Production of Space*, transl. by D. Nicholson-Smith (Blackwell, 1991 [1974]).

and urbanists have propounded about space, we are reminded strongly of the medieval identification of space with pure spirit, with *geist*, one might even say with "*raumgeist*," inextricably bound up with *zeitgeist*. And what is *geist* made of if not information?

Indeed, appropriate to the modern day, I shall try to show that space *is* information, and information space.

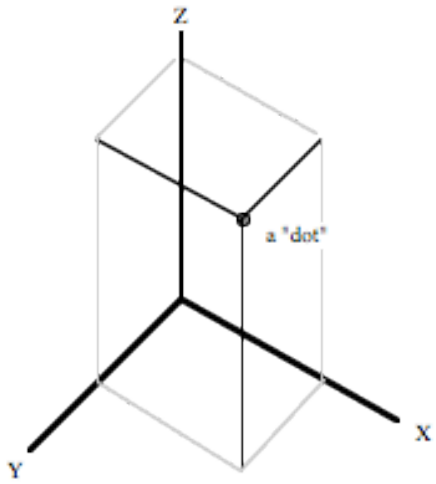
Accounts offered by modern philosophers and scientists, for all their precision, offer us no real alternative. They prove also to rely upon acts of measurement, perception, feeling, counting, referring, and knowing…cognitions all, "spirit" all, *information* all. Even the infinite, absolute, empty night of Newtonian space presupposes a plenum of radiation and gravity with differences in their distribution enough to locate "points" in principle anywhere (and to locate someone or some thing to *take note* of these points anywhere as well). Today we find nothing unusual in talking about mental space, we find nothing unusual or at least unnatural about the perceptual/virtual spaces we created with movies, television, and computers. Space seems both physical and psychological to us, intimately tied up with knowing and perceiving and the idea of freedom.

At the cutting edge of theory about all this, a useful question begins to arise: *is information in space,* or *is space in information?* I submit that this is a pivotal question. In fact, we should get ready to take the next step, which is to explore the more radical idea that *space and information are one and the same "thing."* Consider:

## Thought Experiment I.

We have a computer with which we wish to represent a large body of numerical data to ourselves. The data consists in a set of $\boldsymbol{N}$ strings of $\boldsymbol{n}$ numbers, with $\boldsymbol{N} \geq 3$, and $\boldsymbol{n} \geq 1$. We have no idea what these numbers represent—they may be pictures of a mountain, they may be a record of temperature variations in a nuclear reactor, they may be stock market prices—but we intend to explore the best way to render apparent whatever patterns, whatever order, lurks in the data and to ignore none of it in the process. This mission lies at the heart of the field of endeavor called "scientific visualization," whose task is to manipulate and present complex data to the human mind and nervous system in such a way that they—that *we*—can use our highly evolved and so far inexplicable mental capacity to see patterns in nature, to detect order in space and time. Nevertheless we can begin our search on a logical basis.

We set up a Cartesian coordinate system with the usual axes X, Y, and Z. The positions of $\boldsymbol{n}$ points (more precisely, of $\boldsymbol{n}$ *dots*) in the abstract space created can take care of representing three of the strings of data. Every individual data dot represents, and is represented by, a triplet of numbers $(x_i, y_i, z_i)$. But what if there are two or more data-points (i.e. number triplets) in the data that happen to be the same, and that therefore compete, as it were, for the same dot location? And what of the $(\boldsymbol{N} - 3)$ remaining strings? What do we do with them? Thinking about the second question helps with the first.




One approach would be to generate ***N***/3 coordinate systems, arranged like adjacent rooms, and join the dots in one to corresponding dots in the next, and the next, with ***n*** *multiply segmented lines*. The constituent slopes and lengths of each ***N***/3-times-articulated line would then represent one ***N***-dimensional "data-point" (or row of ***N*** numbers) in the original data.

Another approach would be to devise a way to encode some or all of the remaining (***N*** – 3) strings of numbers as some perceptible quality intrinsic to the dot itself, such as, say, its *color*. Color could take care of three more strings in the form of three *intrinsic dimensions*, "redness," "greenness," and "blueness," which are independent in principle from each other and from the three *extrinsic* or positional dimensions X, Y, and Z. Informationally, a dot without intrinsic dimensions in ***N***-dimensional space, is equivalent to a dot with ***M*** intrinsic dimensions in an (***N – M*)-**dimensional space. In addition to color, or instead, we might give each dot other intrinsic, essentially a-spatial qualities such as spin, or vibration frequency, or even sound.

Now both of these approaches can quite handily attack the problem of how to represent ***n N***-dimensional data-points. Both can minimize the occurrence of competition for a position, but neither can guarantee that a certain number of identical data-points competing for a particular dot or line in the abstract space(s) will not remain . To obviate this last problem we would have to introduce time, or add yet another dimension, intrinsic or extrinsic, to our representation in order to reflect the actual *ordering* of the numbers in the strings.

Now in all this we can see a deep and important principle at work. It was a principle known to Leibniz, who gave it the name of the Identity of Indiscernibles. If the differences between two points, dots, lines, atoms, cats, whatever…he reasoned, are indiscernible, then we do not have two but *one* point, dot, line, atom, or cat. Whatever things we see two or more of are *ipso facto* different from each other *in some dimension*. There are really no two identical objects even when they seem "identical" in all but spatiotemporal location; nature produces no real twins. *Indeed, the three dimensions of* "space" *and the one of* "time" *are simply that handful of dimensions of our much-greater-than-four dimensional reality which form the most capacious coordinate system, which provide the greatest number of opportunities for the identities of things with further inherent qualities to "express" themselves*. Space and time minimize the loss of uniqueness and variety which would otherwise occur amongst the myriad things which, in some sense, *want to be* in our universe.

*Uniqueness and variety exist in some sense prior to space and time, or if not prior, then at one at the same logical moment.* The inhabitants of some other, multidimensional universe would call whichever subset of *their* world-dimensions which served this information-preserving purpose *their* "space" and "time," and they would probably regard the ineluctability and universality of these dimensions with the same, mystified awe we do ours.

With our modest thought experiment we found ourselves engaged in *increasing the amount of space (or time)* available in order *to lose no data* to limited intrinsic dimensions. To the extent that each ***N***-dimensional data-point was unique—if only by one numerical value on one dimension—we sought to maximize the display of its uniqueness. If the conservation of information necessitates the conservation of space, then *the production of new information* in addition *necessitates the production of new space.*

How exciting it was, then, for physicists to discover this space-making law actually at work in nature, and this some 250 years after Leibniz intuited it. Wolfgang Pauli's Exclusion Principle of 1925 states that no two fermions (e.g. electrons) which have the same quantum state (spin, charge) can occupy the same orbital of a given atom at the same time. This single principle explains why the world we know is not condensed to a single, infinite-intrinsic-dimensioned point. Atoms build up shells and layers of electron orbitals "in space" quite literally because there is only "room" for one electron of a kind in a given orbit. The structure of the periodic table of elements and the existence of matter as we know it—all matter—is the result of this kind of limitation, and "atomism" is nothing other than the name of the two-thousand-year-old project to explain (find order) in all natural phenomena while at the same time reducing the number of intrinsic dimensions necessary to their explanation to one, binary-valued dimension, namely: existence/non-existence.

The idea of *room* and the *fact* of space, then, are entirely the outcome of Nature attempting to resolve and manifest her own, evolving, particulate complexity to the utmost degree. It is as though the Matrix—the Mother—wished to represent herself to herself through us entirely and without omission; as though Reality were a cosmic "scientific visualization" of itself, expanding only because it is growing more complex.[4]

Need I point out to the reader the parallels here between the informational spatiologic of nature and that of cyberspace? Consider:

## Thought Experiment II

Another area of scientific inquiry which can throw some light on the issues that concern us is a new subdiscipline situated at the intersection of biology and computer science. It goes by the name of Artificial Life (AL), or Cellular Automata (CA) theory , the latter term going back to John von Neuman's ground-breaking work in the 1950s. In both, life processes such as reproduction, group interaction patterns, and evolution are simulated by allowing a computer to "play out" simple programs assigned to "cells" over time. Always, each cell's behavior depends not only on its inner, given program but on the condition or state of its neighboring cells. As the immediate environment of each cell changes, the cell responds by changing *its* state or behavior accordingly. It thereby constitutes part of the altered environment of the cells to which it is neighbor in turn.

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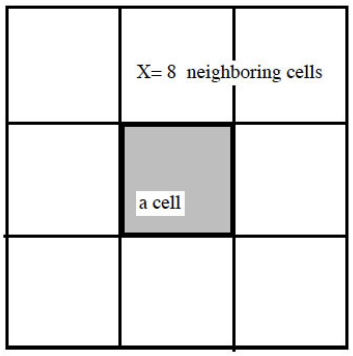
[4] For a complementary perspective on this principle see Julian Barbour, "Maximal Variety as a New Fundamental Principle in Dynamics", *Foundations of Physics*, Vol. 19, 1989, pp.1051--1073.

*En masse*, results are often marvellous and unpredictable. When each cell is represented by a group of pixels, large scale patterns can spontaneously develop on the computer screen. Whorls and waves develop, clusterings, migrations, and dispersals. Individual digital "creatures" evolve and die off, to be replaced (in certain systems) by smarter ones. There are predators and parasites, eras of calm, eras of warfare…etc. etc. And all this, as I noted, can come about with rather elementary beginning programs, programs in the order of 20 to 40 lines of code assigned to each cell. Complexity not apparent at the start develops over time by leaps and bounds, and all the more so if the initial cell programs are revisable by certain events in the cell's history.

Now, for many people it would be much too far fetched to draw parallels between cells in a AL/CA system and individuals in a society. There may be some analogy to termite behavior perhaps, they would say, but not to humans! The far-fetchedness of an analogy depends, however, on the specificity of its claims. In this case, I believe, something rather interesting and relevant can be said about *all* social organizations before the limits of plausibility are reached.

For example, consider some simple informational accounting:

Let $B$ be the number of behaviors (or states) that a cell can display both to us, as observers, and to its neighbors in "screenworld." Let $X$ be the number of cells in the effective neighborhood of any given cell. If the particular behavior of a given cell *depends* on the combined behavior of the ones around it—i.e. the ones in its effective neighborhood—then each cell must, by virtue of its program, have the capacity to perceive, remember, and process the $B^x$ possible states of its effective neighborhood in order to decide what to do next. Now if $x > 1$ and $B > 1$ then clearly $B^x$ is a quantity greater than $B$—easily *much* greater. From this we learn that no cell can behave in as many distinct ways as the ensemble of its similarly adept neighbors can. Each cell('s program) therefore must engage in some sort of decision making, filtering, or blurring process that *reduces* $B^x$ to $B$. Each cell must be able to register $x\log_2 B$ bits of information, manipulate it--condense it, add it up, average it, even discard parts of it—and then *produce* $\log_2 B$ bits of information for display.




What does this mean for *us*? Think of a cell as a human individual. The greater the number of behaviors she allows herself and others to engage in and display ("$B$"), and the greater the number of friends, neighbors, and objects she interacts with ("$x$"), then, quite precisely, the exponentially greater ("$B^x$") is the possible complexity of what the environment she must deal with. And if Thought Experiment I holds any water, then greater too is the amount of *space* is required for that information to exist.

Space? Just where *is* this space? *What* is this space?

It is not the space of "screenworld." Screenworld acts out another, global history (which is interesting enough). It is, rather, the space locked up, as it were, in the domain of each cell, in the imagination of each mind. Seen from above, from outside, the abstract motion of data-points within intrinsic dimensions is visible as "behavior" of $\log_2 B$ bits in complexity. But inside, the remaining $(x - 1)\log_2 B$ bits are at play.[5]

> *I am in an open air market in Rome. It is April. Heaps of fruit and vegetables—tomatoes, squash, red peppers, no two the same—shine in raw wooden boxes under yellow canvas awnings. Water glistens black between the cobblestones under me. The air is filled with the sounds of traffic and voices, each from a unique direction. The smell of fresh fish wafts in a wayward breeze, then cheese, then coffee. To my right is a fountain and sculpture in white marble: figures caught in ecstatic agony, struck in sunshine against a shady Baroque facade, and in the blue, blue sky I see the contrail of a jet airplane headed west, away from the sun.*
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> *Why do I see all this, this excess of detail that I can do nothing about? Precisely because I can do nothing about it! I am a dam, a delay; and this information is accumulated behind me and in me like a lake. A world is constituted in me because the world cannot flow though me un-judged, unreduced. I can respond with actions and thoughts to a vanishing fraction of the welter of information I can perceive, and I "perceive" only because I cannot respond fast enough. Think: were it not this way, were to I have a specific and instant response for every bit of data entering my system, then I would be nothing but a "throughput" device with a passive display; I would be like a billion-stringed puppet, a crazed switchboard, a rail-yard of lightning-quick trains, like a pile of mirrors or a glass chandelier in the sun…each quite beautiful perhaps but quite dead, without consciousness. There would be no world in me, pooled in me, circulating, evaporating, being filtered.*
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> *The street market that is in my head is a holding action. In other words, just as stomachs make it possible for creatures not to eat all the time, so consciousness makes it possible for us not to react all the time, to hold a world behind my eyes and posit it before my eyes…while I decide what do next.*

In sum: the production of spatiotemporal consciousness of a "world" is a consequence—though no *mere* consequence—of surfeit, of the surplus of information that surrounds each one of us relative to our capability of answering to it: $B^x >> B$.

Our second Thought Experiment, then, is not about data representation alone but about its accumulation and processing. Both of these require not just sufficient neurological/computational complexity—a question of hardware—but also, phenomenologically, sufficient *imaginal room* to take place.

Moreover, as time goes by in an *evolving* CA system, the whole system grows rapidly in complexity. If cells' programs are revisable, then the short-cuts, summaries, and decision routines which the first programs employed and which capitalized upon the redundancy in the cell's environment, soon cease to be effective. No longer can they hold and conserve and distill all the information about the environment that they need to. Rather, if the cell is to

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[5] $(x - 1)\log_2 B$ is a very conservative number of course, something of a minimum, since it excludes the contents of memory as well as the process of self-perception.

survive and proliferate, these programs are obliged to become more complex, longer, "smarter," and do. As screenworld—and, dare I say now, as *society*—complexifies in its external, spatiotemporal dimensions, and as individual (cell) behaviors increase in number and complexity and range of perceptibility, then so too, and ever faster, must the internal world of each individual cell expand in order to embrace the new information.[6]

In all, this is a model of *space producing itself* as a correlate of the proclivity of complex, dynamical systems to generate more complexity, more information, in themselves. It is also, I think, a model of what Henri Lefebvre's wants to call *social space*, i.e. the space that exists chiefly by virtue of minds in a nexus of information exchange with one another, and that exists chiefly *in* those minds rather than in the physical world. (This is not to say, of course, that figures in physical space cannot be inscribed by figures in social space, just as screenworld may display some patterns fractally similar to patterns found within each cell's "imaginal realm," were we to display that intrinsic activity.)

Now, the reader may wonder why I have gone to such lengths and technicality to elaborate upon what amounts to a the quite modest claim, the claim, that is, that as environments become more complex, and as effective neighborhoods (as defined) become larger and/or more complex, individuals within them are apt to have, and to *need* to have, "more on their minds." Indeed, this is not very startling. To this self-evident insight I am adding only the perhaps more radical notion that 'more on our minds' means more *in* our minds, and that this means *more space in the world* in a very important sense. For if we can say that "the world" either reduces to, or that it contains as part of itself the set-theoretic union of all inner worlds, we need only now relax our strictures as to the legitimacy of sources of information to see that cyberspace, which Gibson once called "a consensual hallucination," is but a pattern woven into the same informational tapestry as caused in me the experience of the market place in Rome.

## Thought Experiment III

Thought Experiment III is less a thought experiment than a real one: for a good portion of what I will relate to the reader here has been tested empirically. Also, rather than dealing with abstract space, it deals directly with real space, with urban space, and our perception of it. I bring it to the reader's attention because it involves a rather unique treatment of the topic, one that shows as fundamental the fact that *the "shape of a space" is itself* (a) *the information in that space*, and (b) *the space in that information.* [7]

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[6] It is, of course, a hopeless quest: $B^X$ is always greater than $B$, and we do not have the space here (!) to go into the various strategies that people actually use subjectively to balance the equation nonetheless, this in order to live without the feeling of being overwhelmed or incompetent.

[7] Once again, my aim is to demonstrate ways in which the everyday world can profitably be thought of as *information* as well as "the world" as it appears to us so compellingly. There is a certain strangeness in adopting this perspective, of course. The theory of information is a great leveler. Like space, everything turns out to be information…if we define information broadly enough.

This universality, this danger of indifference to specific content, feeling, form ("hey, it's *all* information to *me*") is, however, more apparent than real. As general as it is, the concept of information is a considerable few rungs "higher" than that of space or time alone. The very definition of "information" presupposes a sentient observer who is able to assess likelihoods and to have expectations, someone or some creature that is sensorially and temporally connected to, and part of, the world he or she

Space itself can have no shape, of course; light scattering objects and surfaces can, and certainly this is what is really involved when artists, sculptors, and architects work so hard "to shape a space." Walls and ceilings, buildings and trees, statuary and earthworks are positioned in such a way as to modulate experience: not just the experience of those very walls and ceilings (and buildings and trees...), but the experience of the other people and signs and images and machines and so on that move about and populate the room or cityscape. In other words, the disposition of enclosures and screens and plays of ground elevation, etc., do more than make architectural spaces, they *regulate the presentation* of the rest of world's contents to its inhabitants, pacing it, segmenting it, ordering it in importance, controlling its density. In the unpopulated desert as on a polar ice shelf, the play of visibility and invisibility takes another form; the boundares of one's vision are limited by atmospheric conditions or hardly at all precipitating an experience of a different sort where the contents of space, the smallest presence of animal or human or shelter, looms psychologically large and the world-blocking, space-shaping value of one's own clothing—a shroud around the face, a fold in a sleeve—or of another's body close by, soars even higher. But I speak here chiefly of built worlds. Any "grammar of forms" that would hope to help designers do their job would have to be one that took account of both these functionalities: space as form(ed) *qua* space, and space as a medium of information transmission, where that information is itself sedimented in space in a way that tells of its sources: where they are, what they are, and even why.

To this end, the Theory of Isovists was developed.[8] Stated most simply, an *isovist at x,* denoted $V_x$ , is the set of all points in an environment of opaque surfaces that are visible to a given point, x. (The spherical limit of the isovist is an artificial one, shown in Figure 1, functioning something like a horizon in the absence of any other intervening surfaces.)

Now, isovists have a shape and a size, and every point x in an environment generally has, belonging to it, a uniquely-shaped isovist. Even in a perfectly convex room, where isovist shape and size do not change with observer position in the room, the position of x relative to the isovist boundary does, and this affects various informational "measures" we are interested in. What are some of these measures? (For simplicity's sake we will think of two dimensional isovists, in plan, being horizontal sections through full, three-dimensional isovists.)

Five measures prove to be useful: A, the area of the isovist, which gives us a measure of size (in 3-D this is a volume); *P*, the perimeter of the isovist, which gives us a measure of the boundary length (in 3-D this is an area, of course) excluding the horizon and excluding *Q*, which is a measure of the length (area) of the radial, component of the isovist boundary; $M_2$ , which is a statistical measure of the variability of the boundary's distance from x; and $M_3$, which is a measure of the asymmetry of $M_2$. To fully understand these measures, their

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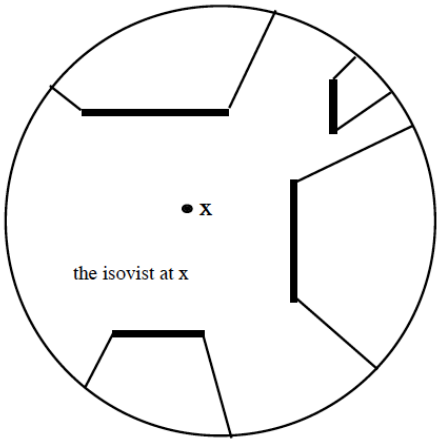
(or it) is perceiving. The concept of information leads very naturally to concrete ideas about order, organization, complexity, knowledge, and even *value* for example. Space and time themselves cannot.

[8] See Michael Benedikt, "On Mapping the World in a Mirror," *Environment and Planning B*, Vol. 7, 1980, pp. 367-378; Michael Benedikt, "To Take Hold of Space: Isovists and Isovist Fields," *Environment and Planning B*, Vol. 6, 1979, pp. 47-65; Michael Benedikt and Larry S. Davis, "Computational Models of Space: Isovists and Isovist Fields." *Computer Graphics and Image Processing*, No. 11, 1979, pp. 49-72.

computation and their meaning, the reader is referred to the references in Note 13. Here, necessarily, I shall be very brief.




It is clear, for example, that as we move around urban space, from street to square to lobby to elevator to office and so on, the *size* of our isovist changes. Conversely one might say that an elevator interior is characterized by low values of *A*, and an urban plaza by high values of *A*. Similarly, a forest is characterized by high values of *Q*, and a ballroom, which may have a comparable value for *A*, will have a low value for *Q*, even a *Q* of zero if there are no columns, corners, or obstructions. A tight enclosure, open only on one side like a cave, has very high $M_3$, while on top of a mountain or on an outside corner of a building $M_3$ is very low, even negative in value. Near the walls of a room, no matter what its shape, the values of $M_2$ and $M_3$ rise steeply, like a meniscus. On the open plains, $A >> 0$ , and $P = Q = M_2 = M_3 = 0$. And so on.

In short, spaces, and locations in them, can be more and more closely characterized by (1) the absolute values of these five measures at that location, (2) by how theses five values change with arbitrarily small motion of the observer in any direction, and (3) by how these values are distributed, field-like, throughout space. *A*, *P*, *Q*, $M_2$, and $M_3$ are intrinsic dimensions of x, values within which happen to be indexed the disposition of surfaces in the (visual) environment around x (itself a point in space whose extrinsic dimensions, of course, are X, Y, Z, and T.)

Are we sensitive to any or all of our five measures of isovist shape and size walking about in the real world? Or are they all mere mathematical inventions? Between 1979 and 1982, with a grant from the National Science Foundation, perception psychologist Clarke Burnham and I tried to find out. The specific research question was this, can our judgment of *spaciousness* be affected, and hence predicted, by any or all of the isovist in an enclosed architectural space of arbitrary shape? The answer was, and is, most decidedly: yes. Our impression of spaciousness is evoked by high *A*, low *P*, low *Q*, and high $M_3$ ($M_2$ seemed to make little difference). Urban spaces and parts of them that have these characteristic values--relative to the local norm—will be perceived as more spacious than those with any other combination.[9]

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[9] Michael Benedikt and Clarke A. Burnham, "Perceiving Architectural Space: From Optic Arrays to Isovists," in *Persistence and Change*, W. H. Warren and R. E. Shaw eds. (Hillsdale, N.J.: Lawrence Erlbaum, 1984), Chapter 6.

Prior to our research, a number of preliminary studies had been carried out. Where would a solitary guard in a museum place his chair? Surely where *A* and/or *P* was highest, and *Q* lowest. Indeed, upon calculations based upon drawings, a visit to the Michener Museum on my campus found the guard and his chair within feet of the predicted spot.

If you ask people to point to landmarks they cannot see (from where they are), their mis-pointing is predictable from an analysis of the radial distribution of *Q*.

If you wish to see but not be seen, choose high *A* and positive $M_3$, if you wish to be see *and* be seen, choose high *A* and negative $M_3$.

What do we consider a "good view?" High *A*, $M_3$ and *Q*. Where is the best place to hide? Low *A*, low *Q*, High $M_3$. Which apartment can I safely break into? Low *A*, low *P*, high $M_2$ and $M_3$

A classical "architectural space" is merely a region of the isovist information field where the *rate of change* of *A*, *P* and *Q* is relatively low; a "threshold" is one where these rates of change are high. Modern architectural space, "restless" and "flowing," is characterized by sustained high levels of *Q* and $M_2$, while rates of change of *A*, and *P* are moderate.

And so on.

It is easy to accept that football and soccer players must see "isovistically" quite directly as they negotiate the changing array of depths and proximities around them. So, as hunter and hunted judge their relationship to each other and the world, so do most animals; and indeed, so do *we* most of the time make this judgment. The "painterly eye" and, with it our, pictorial or cinematographic understanding of space was a long time in evolving. Billennia, in fact. As J. J. Gibson argued, the world is seen first (i.e. most immediately) in terms of the dynamic and volumetric play of depths- and distances-from-us. Only secondarily, only derivatively, is it seen in terms of a static pictorial layout of surfaces across our vision as in a painting or photograph or on a video screen. It is as though natural seeing were like sonar or radar, that is, *extended touch*, before it was seeing in the camera-image sense. Isovist information lies deeper and more salient to us than its pictorial transforms, and this is why the technology of "virtual reality" promises so much. It is the only medium of representation other than theatrical re-creation a lá Disney that can tap directly into the sense of surroundingness, self-to-object depth, and even real touch, directly.

With the theory of isovists, we have a description of the world in its spatial aspects that permits us to study experience over time and with motion. More than this, however, isovists provide us with a way of understanding space itself as neither logically prior nor subsequent to isovists and the information they contain. Isovist measures constitute a class of information about (visual) space. But it is equally true to say that (visual) *space is partially constituted by the structure of, and in, isovistic information*. Extrinsic and intrinsic dimensions turn out, in this case, to mirror one another. We can neither trust one more than the other, nor claim one to be more real than the other. Isovist information is embedded in/at every point in space, *as* "that point in space," *as* space.

Whether, then, we look at the positioning of architectural surfaces from outside, in a neutral, Cartesian manner as when we look at plans and sections and try to predict the experience of the space and its contents from within it, or whether we look at fields of isovist data not knowing or seeing the surfaces that "caused" them; whether we watch a movie of motion though that space or whether we experience that space in VR, or in reality, the results can be the same. The results can be the same because the information is the same, and the

information is the same because, ultimately, the space in information and the information in space are one.

## Space Fractured and Reconstituted: Telecommunications, Remote Sensing, and Cyberspace,

What are "telecommunications?" Typically we associate the term with the transmission of information via electronic and electromagnetic means from one point on the surface of the earth to the other (although with space flight and satellite photography, the latter constraint is jettisonable). We mean telegraph, telephone, television, radio and so forth, as well as their new recombinations. Of course, information travelled across large-scale geographical space by report, rumor, and letter, in minds, boxes, and satchels, long before telecommunications made it so fast and easy. To this day, human agents on foot, horseback, boat, plane and truck deliver vast amounts of information in discrete (and usually discreet) *parcels* or packets whose inscription method resisted erasure by the information's natural tendency to entropic dissolution. Important to note is that unlike information that is "broadcast"—from the voice of a town crier and the peal of bells to the sight of a poster and commercial (pre-cable) television—much of the information physically transported in parcels *does not exist in the space between those parcels*. It cannot be picked up at any time and/or over a continuously extended region. Rather, one must be in direct receipt of the relevant parcel somewhere specific, for example, *at* one's "address" or "phone number." Moreover, unlike direct vision and direct sound and unlike, to a lesser extent, broadcast TV and shortwave radio, there is a very small penalty for distance from the source, even less for direction from the source, and little or no interference from geographic "blockages."[10]

This means that whatever imaginal spaces unfold from within the parcel, be it from a videotape, or book, or photograph, they remain both located in local geographic space and largely independent of it. One can read a novel (almost) anywhere: the story does not know where it is being read, or by whom. Over smaller regions, ditto the radio. When one is "on the telephone" one is...where?

Now, real space—urban space—neither affects nor is affected by such re- or dis-located information except by what I would call *cognitive occlusion*. For, as argued earlier, it is simply not the case that we live in this physical world only. With limited attention and with limited life-times, we live *in* information, and much as architects would have it be otherwise, only a small portion of this information is about, or comes from, the people, streets, and buildings present around us. A video camera set up in one place in the city and cabled to a monitor in a second place in the city (or to another city, for that matter) can so channel our attention that consciousness of the second place is occluded by the first. We have already made mention of the Walkman. How much neglect of the physical environment has to do with our living less and less of our lives *in* it in the informational sense is something we shall want to discuss. With a Landsat picture one can gaze down at the earth from a hundred miles high and see patterns which reduce the earth's surface to an abstract, if

[10] Interestingly, cellphones, which due to their operating frequencies and low power are particularly susceptible to real geographic constraints, overcome them precisely by creating a network of multitudinous receiver/transmitters, as little as a few hundred feet apart in cities, and connected via microwave links to geostationary satellites in order, phenomenologically, to simulate a noiseless and lossless broadcast medium impervious to geographical distance and circumstance.

weathered, painting, or, knowing what one is looking at, at the same time create a most vertiginous dislocation of our consciousness.

The ability of dis-located information to cognitively occlude one's surroundings is a function of only two factors: (1) the relative *salience* of the dis-located (and dis-locat*ing*) information, and (2) its sensory dominance. A lack in one factor can fairly substitute for a lack in the other. An intriguing postcard and a boring movie can, on balance, be equivalent in their environment-occluding effect as the wiping out of the world and replacing it with another.

Let us turn to those two latest development in information technology, namely, the *networked computer*, and the technology that goes by the name of "virtual reality" or VR. The first excels at salience, the second at sensory dominance, and the two together could significantly displace reality as we know it.

Begin with the Internet. It consists of roughly 4000 complete networks of computers linked to each other worldwide, each with several "gateways" to all the others. The traffic in data is already staggering: some 5 to 10 million people worldwide are personally connected through Internet, sending email, messages, data, pictures, sounds about God-knows-what to each other. Traffic on Internet alone has been growing at the rate of 20% per month for the last five years. In the United States, a non-profit group called Advanced Network is completing a network that will transfer data at 622 million bits a second, 60 times as fast than the current speed recod held by NSFNet. However, this is still slower than the future terabit network now being developed in the U.S. with Federal Government support. This will transfer data at a *billion* bits/sec, and more. The Federal Communication Commission recently licensed regional telephone companies to transmit commercial television and video information services for the first time via optical fiber. More deregulation awaits. This will mean the end of cable company monopolies, and the beginning of a new era of computer integrated interactive entertainment, consumerism, and education. Hardly a week goes by without a some major alliance formed between global communication, computer, and entertainment companies.

What we are witnessing is not just the connecting of real places, urban spaces, together--as with plumbing or wiring--but the creation of a new medium entirely where real geographic place is irrelevant. More than just sensorially connecting distant real places that is—say with pictures and sound, and various telepresence VR systems, and therefore making these places adjacent to each other, or even interchangeable—information in the quantities we will be dealing with, enables the creation of fictional, consistent, wholly electrical "third" spaces, places that exist nowhere and everywhere, whose light shines only in eyes and not on trees or streets. Rather than what Manuel Castells, following Henri Lefebvre, calls "the space of flows," referring to the flow of money and information through telecommunications, this is the space *in flows* sensorially reconstituted as space: as urban space, as architectural space, as urban space and abstract space all together… reconstituted, namely as *cyberspace*. There may well be hundreds of cyberspace domains someday, with unique cultures and purposes, not disimilar to countries.

And of what do these "flows" consist? Of information, to be sure, but effectively—phenomenologically—of power, money, symbols, news, the presence of other people, decisions, proposals, reports, linkages, references, affirmations, laws, entertainments, conferences, classes, stories, real and imaginary images...where shall I stop? As I have tried to demonstrate with my three thought experiments, information is intrinsically spatio-temporal, and cyberspace is merely the name given to information spatio-temporalized in a specific way.

Add to this now head-tracking 3-D video-monitors, position-sensing large scale and head-mounted displays, "data gloves," "data suits" and all the other paraphernalia of VR that allow electronically generated worlds to take sensory dominance over the local architectural environment. And add also the new wells of geographic data being provided by remote sensing devices in orbit and on the ground. Add as well as the forms and phantasms lurking in scientific data pouring from machines and sensors and cameras world over.

In his book *The Informational City*, Castells makes note of the enormous expenditure on telecommunication equipment by US business creating geographically nondescript landscapes of anonymous office buildings. "This is the best example," he writes, "of the direct relationship with location in a given place as a means (only) of access to the *placeless communications network*.."[11] He is right of course, except that with cyberspace that 'communications network' is no longer placeless. Or rather, need not be. Shoshana Zuboff, in her book *In The Age of the Smart Machine,* makes a similar point: computerization cuts people off from each other, from place, physical intuition, and sensory reality.[12] Once again, this is only true until cyberspace and VR technology can reconstitute and recover the space hidden, as it were, in the dimensions of pure information.

I am an architect. I am interested in my profession and its future, and I should like to conclude with a few thoughts on the matter. Cyberspaces will require constant planning and management. From the viewpoint of the discipline and art of architecture itself, cyberspace can be seen as extending an inexorable process that began a long, long time ago and which gained new impetus earlier this century, namely, the *dematerialization* of buildings. Indeed, architecture's most progressive practitioners and theorists of the day are already approaching the limit, the last steps, of the conversion of architecture's proper constructional and material discourse into its purely intellectual, graphical, cinematic, and logical content. It is with the development of virtual reality technology and of high speed computer networks, with the technologies of on-site cinematic projection, remote sensing, data visualization and place appropriation represented here by "Now—The Polar Space," that these "last steps" of architecture, rather than regrettable can be welcomed, not as last steps at all, but the first unwitting steps into a new, parallel, and alternative architecture, into a new, parallel and alternative realm for Being called cyberspace. •

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[11] Manuel Castells, *The Informational City,* (Basil Blackwell, 1989) p. 349. My parenthesis and emphasis.

[12] Shoshana Zuboff, *In The Age of the Smart Machine* (Basic Books, 1988).