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THE N-DIMNESIONAL GEOMETRY AND KINAESTHETIC SPACE OF THE INTERNET

Abstract: The article considers the visual conventions used by graphical user interfaces in light of the visual understanding of modern art and science. The key role of two-dimensional visual conventions, like “windows”, in web design, and the history and psychology of such conventions, is reviewed. The article explores whether two-dimensional imaging is an adequate representation of virtual space, and it examines the way in which haptic and kinetic behaviours associated with web browsing compensate in part for the limits of two-dimensional interfaces by stimulating imaginary third dimensions. The article also considers whether higher-dimensional geometries of “hyper-space” provide clues about the way in which virtual space could be represented, and the practical benefits of this.

INTRODUCTION

What does the space created by the Internet look like? One answer to this question is to say that, because this space exists "virtually", it cannot be represented. The idea of things that cannot be visually represented has a long history, ranging from the Romantic sublime to the Jewish God. A second, more prosaic, answer to the question of what cyberspace looks like is to imagine it as a diagram-like web. This is how it is represented in "maps" of the Internet. It appears as a mix of cross-hatching, lattice-like web figures, and hub-and-spoke patterns of intersecting lines.

This latter representation, though, tells us little more than that the Internet is a computer-mediated network of data traffic, and that this traffic is concentrated in a handful of global cities and metropolitan centres. A third answer to our question is to say that Internet space looks like its representations in graphical user interfaces (GUIs). Yet GUIs, like all graphical designs, are conventions. Such conventions leave us with the puzzle: are they *adequate* representations of the nature of the Net and its deep structures?

Let us suppose that Internet space can be visually represented, but that diagrams of network traffic are too naïve in nature to illustrate much more than patterns of data flow, and that GUI conventions may make misleading assumptions about Internet space, the question remains: what does the structure of this space actually look like? This question asks us to consider the intrinsic nature, and not just the representation, of the spatial qualities of the Internet. One powerful way of conceptualising this nature is via the concept of hyperspace.

The term hyperspace came into use about a hundred years before the Internet (Greene, 1999; Kaku, 1995; Kline, 1953; Rucker, 1984; Rucker, 1977; Stewart, 1995;

Wertheim, 1999). In the course of the following century, a number of powerful visual schemas were developed, in both science and art, to depict it. These schemas were developed to represent the nature of four-dimensional geometry and tactile-kinetic motion—both central to the distinctive time-space of twentieth-century physics and art. When we speak of the Internet as hyperspace, this is not just a flip appropriation of an established scientific or artistic term. The qualities of higher-dimensional geometry and tactile-kinetic space that were crucial to key advances in modern art and science are replicated in the nature and structure of space that is browsed or navigated by Internet users. Notions of higher-dimensional geometry and tactile-kinetic space provide a tacit, but nonetheless powerful, way of conceptualising the multimedia and search technologies that grew up in connection with networked computing in the 1970s-1990s.

BACKGROUND

The most common form of motion in computer-mediated space is via links between two-dimensional representations of "pages". Ted Nelson, a Chicago-born New Yorker, introduced to the computer world the idea of linking pages (Nelson, 1992). In 1965 he envisaged a global library of information based on hypertext connections. Creating navigable information structures by hyper-linking documents was a way of storing contemporary work for future generations. Nelson's concept owed something to Vannevar Bush's 1945 idea of creating information trails linking microfilm documents (Bush, 1945). The makers of HyperCard and various CD-Rom stand-alone computer multimedia experiments took up the hypertext idea in the 1980s. Nelson's concept realized its full potential with Berners-Lee's design for the "world wide web" (Berners-Lee, 1999). Berners-Lee worked out the simple, nonproprietary protocols required to effectively fuse hyper-linking with self-organized computer networking. The result was hyper-linking between documents stored on any web server anywhere in the world.

The hyper-linking of information-objects (documents, images, sound files, etc.) permitted kinetic-tactile movement in a virtual space. This is a space—an information space—that we can "walk through" or navigate around, using the motor and tactile devices of keyboards and cursors, and motion-sensitive design cues (buttons, arrows, links, frames, and navigation bars). It includes two-dimensional and three-dimensional images that we can move and manipulate. This space has many of the same characteristics that late nineteenth-century post-Euclidean mathematicians had identified algebraically, and that early twentieth-century architects and painters set out to represent visually.

The term hyperspace came into use at the end of the nineteenth century to describe a new kind of geometry. This geometry took leave of a number of assumptions of classical or Euclidean geometry. Euclid's geometry assumed space with flat surfaces. Nicholas Lobatchevsky and Bernhard Riemann invented a geometry for curved space. In that space Euclid's axiom on parallels no longer applied. In 1908, Hermann Minkowski observed that a planet's position in space was determined not only by its x,y,z coordinates but also by the time it occupied that position. The planetary body moved through space in time. Einstein later wedded Minkowski's hyperspace notion of space-time to the idea that the geometry of planetary space was curved (Hollingdale, 1991; Kline, 1953; Greene, 1999).

Discussion of hyperspace and related geometric ideas signalled a return to the visualization of geometry (Kline, 1953). Ancient Greeks thought of geometry in visual terms. This was commonplace until Descartes' development of algebra-based geometry in the seventeenth century. Euclidean geometry depicted solids in their three dimensions of height, width, and breadth. The seventeenth century co-ordinate geometry of René Descartes and Pierre Fermat rendered the visual intuitions of Euclid's classical geometry into equations—that is, they translated the height, depth, and breadth of the x,y,z axes of a three-dimensional object into algebra. In contrast, in the twentieth century, it was often found that the best way of explaining post-Euclidean geometry was to visually illustrate it.

This "will to illustrate" was a reminder of the traditionally close relationship between science and art. Mathematics was common to both. It is not surprising then that post-Euclidean geometry was central not only to the new physics of Einstein and Minkowski but also to the modern art of Cézanne, Braque, and Picasso (Henderson, 1983). In turn, the visualised geometry of this new art and science laid the basis for the spatial intuitions that regulate movement and perception in Internet-connected multimedia environments. In geometric terms, such environments are "four dimensional". In aesthetic terms, such environments have a "cubist" type of architecture.

Technologies that made possible the navigable medium of the Internet—such as the mouse, the cursor, and the hypertext link—all intuitively suppose the spatial concepts and higher dimensional geometries that typify Cézanne-Picasso's multi-perspective space and Einstein-Minkowski's space-time. The central innovation in these closely related concepts of space was the notion that space was not merely visual, but that the visual qualities of space were also tactile and kinetic. Space that is tactile and kinetic is fundamentally connected to motion, and motion occurs in time. Space and time are united in a continuum. The most fundamental fact about Internet or virtual space is that it is not simply space for viewing. It is not just "space observed through a window". It is also space that is continually touched—thanks to the technology of the mouse and cursor. It is also space that is continually moved through—as users "point-and-click" from link to link, and from page to page. Consistent with the origins of the term, the hyperspace of the Internet is a form of space-time: a type of space defined and shaped by movement in time—specifically by the motions of touching and clicking.

CRITICAL ISSUES

When we look at the world, we do so in various ways. We can stand still, and look at scenes that either move across our visual field or else that are motionless. When we do this, we behave as though we were "looking through a window". The window is one of the most powerful ways we have for defining our visual representations. The aperture of a camera is like a window. When we take a picture, the window-like image is frozen in time. The frame of a painting functions in the same way. Whether or not the scene depicted obeys the laws of perspective, the viewer of such paintings is defined (by the painting itself) as someone who stands still and observes. Even film—the moving picture—normally does not escape this rule. Its succession of jump cut images are also a series of framed images.

Windows and window-frame metaphors dominate GUI design. Graphical user interfaces enabled the transition from command-line to visual processing of information. From their inception, GUIs were built on the metaphor of windows. Ivan Sutherland at MIT conceived the GUI window in the early 1960s—for a computer drawing-program. Douglas Engelbart reworked the idea to enable multiple windows on a screen. Alan Kay, at Xerox's Palo Alto Center, devised the mature form of the convention—overlapping windows—in 1973 (Head, 1999; Gelernter, 1998).

“Looking through a window”, however, is not the only kind of visual experience we have. Much of our looking is done “on the move”. Sometimes we move around still objects. This experience can be represented in visual conventions. Many of Cézanne’s paintings, for example, mimic this space-time experience (Loran, 1963). They are composed with a still object in the centre while other objects appear to circulate around that still centre. Motion is suggested by the titling the axes of objects and planes. What the artist captures is not the experience of looking through a window into the receding distance—the staple of perspective painting—but the experience of looking at objects that move around a fixed point as if the observer was on the move through the visual field.

Sometimes this navigational perspective will take on a “relativistic” character—as when we move around things as they move around us. The visual perceptions that arise when we “walk-through” or navigate the world is quite different from the frozen moment of the traditional snap-shot. In conventional photography we replicate the sensation of standing still and looking at a scene that is motionless. In contrast, imagine yourself taking a ride on a ferryboat, and you want to capture in a still photo the sense of moving around a harbour. This is very hard to do with a photographic still image.

The development of the motion camera (for the movies) at the turn of the twentieth century extended the capabilities of the still camera. A statically positioned motion camera was able to capture an image of objects moving in the cinematographer’s visual field. The most interesting experiments with motion pictures, however, involved a motion camera mounted on wheels and tracks. Such a camera could capture the image of the movement of the viewer through a visual field, as the viewer moved in and around two-dimensional and three-dimensional (moving and static) objects. This was most notable in the case of the tracking shot—where the camera moves through space following an actor or object.

It was the attempt to understand this kind of moving-perception (the viewer on the move) that led to the discovery of the idea of hyperspace. Those who became interested in the idea of moving-perception noted that conventional science and art assumed that we stood still to view two-dimensional planes and three-dimensional objects. But what happened when we started to move? How did movement affect perception and representation?

It was observed that movement occurs in time, and that the time "dimension" had not been adequately incorporated into our conventional images of the world. This problem—the absence of time from our representations of three-dimensional space—began to interest artists (Cézanne) and mathematicians (Poincaré and Minkowski). Out of such rethinking emerged Einstein's theories.

Artists began to find visual ways of representing navigable space. This is a kind of space that is not only filled with static two- or three-dimensional objects that an observer views through a window. It is also space in which both observers and things observed move around. This space possesses a "fourth" dimension, the "dimension" of time. In such space, two-dimensional and three-dimensional objects are perceived and represented in distinctive ("hyper-real" or "hyper-spatial") ways.

The painters Cézanne, Picasso, and Braque portrayed the sequential navigation/rotation of a cube or other object as if it was happening in the very same moment (simultaneously) in the visual space of a painting. Imagine walking around a cube, taking successive still photos of that circumnavigation, and then pasting those photos into a single painted image. Picasso's contemporary, the Amsterdam painter-architect Theo Van Doesburg, created what he called "moto-stereometrical" architecture—three-dimensional buildings designed to represent the dimension of time (or motion). Doesburg did not just design a space that could be navigated but also a representation of how our brain perceives a building (or its geometry) as we walk round it. Doesburg's hyperspace was composed of three-dimensional objects interlaced with other three-dimensional objects. This is a higher-dimensional analogue of the traditional Euclidean idea of a two-dimensional plane being joined to another two-dimensional plane to create a three-dimensional object. A hypersolid is a three-dimensional solid bounded by other three-dimensional solids. This type of architecture captures in one image (or one frozen moment) the navigation of objects in time.

In 1913, the New York architect, Claude Bragdon, developed various "wire diagrams" (vector diagrams) with coloured planes to represent this interlacing of three-dimensional objects. The same interlacing of three-dimensional object-shapes also appears in the architecture of the great twentieth-century philosopher Ludwig Wittgenstein, in the villa that he designed for his sister in Vienna in 1926 (Murphy & Roberts, 2004). Wittgenstein's contemporary, the Russian artist Alexandr Rodchenko, envisaged space as composed of objects within objects. On the painters' two-dimensional canvas, he painted circles within circles, hexagons within hexagons. If you replace the two-dimensional circle with the three-dimensional sphere, you get a hyperspace of spheres within spheres.

Hypersolids are objects with more than three dimensions [= n dimensions]. One way of thinking about hypersolids is to imagine them as "three-dimensional objects in motion" (a car turning a corner) or "three-dimensional objects experienced by a viewer in motion" (the viewer standing on the deck of a boat in motion watching a lighthouse in the distance). The hypersolid is a way of representing what happens to dimensionality (to space and our perceptions of that space) when a cube, a cone, or any object is moved before our eyes, or if we move that object ourselves, or if we move around that object (Murphy, 2001).

Consider an object that moves—because of its own motion, or because of our motion, or both. Imagine that object captured in a sequence of time-lapse photos, which are then superimposed on each other, and then stripped back to the basics of geometric form. What results from this operation is an image of a hypersolid, and a picture of what hyperspace looks like. Hyperspace is filled with intersecting, overlapping, or nested three-dimensional solids.

In the case of the navigable space of hyper-linked pages (web pages), the perception of hyperspace remains largely in the imagination. This is simply because (to date) graphical user interfaces built to represent web space mostly assume that they are "windows for looking through". Internet and desktop browsing is dominated by the visual convention of looking through a "window" at two-dimensional surfaces. Browsing the net, opening files, and reading documents all rely on the convention of window-framed "pages". The mind, fortunately, compensates for this two dimensional appearance. Much of our three-dimensional representation of the world, as we physically walk through it, is composed in our brain. The brain creates a third dimension out of the two-dimensional plane image data that the eyes perceive (Sacks, 1995). The same thing happens to plane images when we click through a series of pages. While the pages are two-dimensional entities defined by their width and height, through the haptic experience of pointing and clicking and the motion of activating links, each two-dimensional page/plane recedes into an imaginary third dimension (of depth). Moving from one two-dimensional plane to another stimulates the imagination's representation of a third dimension. Our brain creates the perception (or illusion) of depth—thus giving information an object-like 3D character. But linking does more than this. It also allows movement around and through such information objects, producing the implied interlacing, inter-relating, and nesting of these virtual volumes.

Hyperspace is a special kind of visual space. It is governed not only by what the viewer sees but also by the tactile and motor capacity of the viewer and the motion of the object observed. The tactile capacity of observers is their capacity for feeling and touching. The motor capacity of the viewer is their power to move limbs, hands, and fingers. Tactile and motor capacities are crucial as a person moves through space or activates the motion of an object in space. So it is not surprising that we refer to the "look and feel" of web sites. This is not just a metaphor. It refers to the crucial role that the sense of "feel"—the touch of the hand on the mouse—plays in navigating hyperspaces.

In hyperspace, the viewers' sight is conditioned by the viewers' moving of objects in the visual field (for example, by initiating roll-overs, checking boxes, dropping down menus, causing icons to blink), or alternatively by the viewer moving around or past objects (for example, by scrolling, gliding a cursor, or clicking). Yet, despite such ingenious haptic-kinetic structures, the principal metaphor of GUI design is "the window". The design of navigable web space persistently relies on the intuitions of pre-Riemann space.

Consequently, contemporary GUI visual conventions only play a limited role in supplementing the mind's representation of the depth, interlacing, and simultaneity of objects. Whatever they "imagine", computer users "see" a flat world. GUI design for instance gives us an unsatisfying facsimile of the experience of "flicking through the leaves of a book". The depth of the book-object, felt by the hand, is poorly simulated in human-computer interactions. The cursor is more a finger than a hand. Reader experience correspondingly is impoverished. Beyond hyper textual links, there are to date few effective ways of picturing the interlacing of tools and objects in virtual space. The dominant windows metaphor offers limited scope to represent the simultaneous use of multiple software tools—even though 80% of computer users employ more than one application when creating a document.

Similar constraints apply to the representation of relations between primary data, metadata, and procedural data—or between different documents, files, and web pages open at the same time. Overlapping windows have a limited efficacy in these situations. Even more difficult is the case where users want to represent multiple objects that have been created over time for example as part of a common project or enterprise. The metaphor of the file may allow users to collocate these objects. But we open a file just like we open a window—by looking into the flatland of 2D page-space.

CONCLUSION

While the brain plays a key role in our apprehension of kinetic-tactile n-dimensional space, the creation of visual representations or visual conventions to represent the nature of this space remains crucial. Such representations allow us to reason about, and to explore, our intuitions of space-time. In the case of Internet technologies, however, designers have largely stuck with the popular but unadventurous "windows" metaphor of visual perception. The advantage of this is user comfort and acceptance. "Looking through a window" is one of the easiest to understand representations of space, not least because it is so pervasive. However, the windows metaphor is poor at representing movement in time and simultaneity in space. All of this suggests that GUI design is still in its infancy. The most challenging twentieth-century art and science gives us a tempting glimpse of where interface design might one day venture.

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