Graphesis: Visual Knowledge Production and Representation

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Digital technology depends on visual presentation for much of its effectiveness. The ubiquitous graphical user interface and the design of icons for navigation, daily activities and functions, are familiar graphic structures. Higher-level functions using visualization are commonplace for analysis of statistical data. Many creative, original works in all areas of design for industry, art, entertainment, engineering, and technological activity at micro and macro levels are graphically enabled through design. Visual mediation of knowledge has never been more widespread, more commonplace. But critical understanding of visual knowledge production remains oddly underdeveloped. A glance at the philosophical assumptions on which epistemology is grounded show its logocentric and empiricist (statistical) biases. We need to challenge such assumptions to establish a critical frame for understanding visualization as a primary mode of knowledge production.

Mathematician and philosopher René Thom once wrote "… for a phenomenon to be an object of science, counted in the common (and, in principle, eternal) heritage of scientific knowledge, it is first necessary to describe it." He stated that we have only two such descriptive techniques: "natural language and mathematical formalism."[1] He conspicuously excluded graphical description from this list.

Surely Thom must have been aware of the substantial role visual images have played in the history of the natural and physical sciences. William Ivins's landmark study, *Prints and Visual Communication*, showed that engravings made possible the production of "exactly repeatable statements" in visual form that were integral to the advance of modern science.[2] Beginning in the 15^{th} century in Europe (and considerably earlier in Asia), images in scientific and technical publications created a stable, shared reference, initially through wood engravings. The increased detail of line and tone afforded by copper and steel plates extended the graphic range–and consequently the authority–of images. Prints served to mediate scientific knowledge in every sense. They *were* media: a means of inscription that embodied and communicated information in graphical codes. And they functioned to mediate–to serve as a site for focused, inter-subjective exchange among professionals–contributing to the creation of a scientific community.[3]

Even before the existence of print technology, visual images served varied epistemological functions -- from the representation of information in condensed, legible form, to the expression of complex states of mind and experience. Maps, graphs, diagrams, illustrations, pictorial images of all kinds, even handwriting and inscriptions, provide information through graphical means (as images) but also through their specific visual features (texture, syntax, color and other characteristics). Thom's oversight seems peculiar for so astute a thinker.[4] His attitude is reminiscent of the denigration of vision in modern critical theory, described by Martin Jay in *Downcast Eyes.* Visual images have little authority within the long tradition of logo-centrism that dominates western epistemology.[5] Paradoxically, sight was always privileged in the hierarchy of the senses.[6] From antiquity onward, the eye's capability was associated with reason and enlightenment in ways that taste, touch, smell, and even hearing never were. Vision allowed perception at a distance, without direct contact or fleshly stimulation.

The debased status of images in Thom's assessment derives from deep strains of negative stigma bequeathed by the Judeo-Christian traditions that cast a pejorative judgment on all sensual aspects of experience. The promiscuity of images, their capacity to serve so many functions (entertainment, pleasurable distraction, communication), calls their status into question. Even recent critical studies admit that visual images are a less stable form of knowledge production than language. Large philosophical issues and deep-seated prejudices haunt us at every turn.

Historical evidence suggests that a very strong case can be made for visual techniques to generate and represent knowledge. To understand visual knowledge production in digital humanities, we can draw on quite a range of pre-existing work about the ways images encode information. When it comes to using visualization as interpretation, however, our practice is only just beginning to take shape.

We can start by making an inventory of forms to be read as cultural expressions of knowledge. Most of the conventions for information representation have their origins in experimental methods in the sciences. Graphical expressions with their foundations in quantitative approaches assume the cultural authority of objectivity. As we shift these conventions for use in the humanities, we can bring the interpretive sensibilities of theoretical inquiry to bear on these assumptions while also acknowledging subjectivity as fundamental to the conception and expression of knowledge.

Graphesis is defined as the field of knowledge production embodied in visual expressions. This seems straightforward enough. But the range of such expressions is enormous, and defining the principles of a stable symbolic system seems daunting. The term graphical includes specialized writing and notation, codes and symbols. It might also embrace visual art and design. I mean the term to suggest visual expressions that are arrangements of marks or visual forms organized to read on and as a flat surface (in other words, in their literal, visible form, rather than as pictorial illusions). But I intend the term to suggest a more fundamental ground on which to begin to examine the ways all visual expressions work -- whether they are forms of writing, pictorial imagery, information graphics, or other images --*by virtue* of being marks organized on a flat surface. Graphic artifacts present knowledge through the combination of symbolic codes and structured relations of these elements in a flat field. My basic aim is to create a critical framework within which the forms that are generally used for the presentation of information can be understood and read as culturally coded expressions of knowledge with their own epistemological assumptions and historical lineage. A general theory of graphesis addresses the organizing principles of all images for the ways they encode knowledge through visual structures and rhetorics of representation.

If we're going to conceptualize graphesis as visual epistemology at the beginning of the 21st century, we have to establish its foundations on current theories of knowledge. Visual epistemology has to be conceived as procedural, generative, emergent, as a co-dependent dynamic in which subjectivity and objectivity are related.[7] Profoundly interdisciplinary, graphesis draws on the histories of natural and social sciences, administration and management, the humanities and the arts, information design and graphic design (including interface production), vision and cognitive studies as well as conceptual modeling techniques.[8] And visual perception has to be understood as embodied, affective, situated, and circumstantial in physiological, psychological, and cultural terms. While acknowledging the enormity of the considerations introduced in that last sentence, the approach to graphesis sketched here will be focused more on the ideology of forms and the legacy of their intellectual traditions than on the issues of perceptual process.[9]

Graphical knowledge cannot be grasped in any self-evident way. Like any other form of human expression–natural or formal language, mathematical notation, bodily gestures, or other signs and codes–visual imagery becomes more stable and more useful when interpreted in combination with a linguistic gloss or statistical base. This statement doesn't negate the specific properties of visuality–many of which have no equivalent in language or formal systems–but it does put to rest any lingering vestige of naïve formalism premised on an idea of the autonomy or transparency (or *apparency)* of visual representation. No image is self-evident. We learn to interpret through the situated and subjective condition of perception whereby an encoded expression provokes a response for cognitive processing.

Sciences and visual forms of knowledge

Visual images serve the sciences by making use of specific graphical properties. Images embody information though three different modes, each of which has a different structural relation to the referent.[10] They can work 1) through offering a visual analogy or morphological resemblance, 2) through providing a visual image of non-visible phenomena, or 3) by providing visual conventions to structure operations or procedures. Examples of these approaches come from the natural sciences, physical sciences, and mathematics, as well as applied sciences such as engineering. The principles of knowledge production and representation embodied in each approach cuts across these and other disciplinary boundaries to serve humanities and social sciences as well. In distilled form, these principles provide some of the foundations of a general theory of graphesis, particularly within the area of experimental methods for conceptualizing, producing, and representing knowledge.

Morphological analogy

The natural sciences–biology, botany, anatomy, and geology–have a long history of dependence on graphical images. Many of these are premised on analogies between observable phenomena and pictorial representation. Anatomical atlases and herbals are not simply compendia of visible information, they document the schematic presentation of carefully distilled and edited observation. The isomorphism of diagram and specimen depends on an editorial transformation, with all the advantages of clarification and disadvantages of reductive simplification. But the processing of visual stimuli into images involves the mind, not just the eye and hand. The long inventory of distortions, drawings of specimens for which no conceptual classification is yet established argues strongly for the effects of mental images and their influence on perception. We have only to recall the peculiar images of toothed whales drawn from beached specimens or Caucasian featured indigenous Americans or Americans sketched by early explorers to bring vivid examples to mind. [11]

No eye is innocent, as Ernst Gombrich long contended, and mechanistic theories of vision can be readily disproved by observing the force of appetites, desires, or cultural training.[12] The evolutionary biologist J.J. Gibson made clear the effect of such adaptive opportunism on the physiology of vision in his studies of birds.[13] The implications for other species, including humans, are that we see what we have learned to depend on for basic functionality, not what there "is." Our visual and cognitive capabilities conspire in a radical pre-selection of visual stimuli. And our organism adapts itself, lazily–but sensibly–ignoring visual "information" that it seems not to need.[14] Thus the represented morphology gives persuasive cues to the observer, predisposing the eye to see what is already present in the image. As anyone who has ever dissected a specimen in a lab is well aware, the schematic diagram guides vision as much as perception gives rise to any diagrammatic representation. We organize the chaotic messiness of observed experience through the guidance of simplified schema. Morphological analogy *assumes* resemblance in the relation of image and referent.

The experimental approach to scientific investigation that depends heavily on visual models gives shape to the phenomena to be observed and then designs the apparatus suitable for their detection. In the sciences this distinction is reinforced by the difference between the concepts of "data" and "capta." Data are considered objective "information" while capta is information that is captured because it conforms to the rules and hypothesis set for the experiment. The distinction is far more difficult to maintain in practice than to define in theory. We see what we know to look for. Those models continually change, mutated by effect of images and their technological capabilities. The plausibility of dinosaur imagery in popular imagination has a direct relation to the use of increasingly photographic properties of realism. Disciplinary and cultural shifts in knowledge are marked in and effected by such changes.

Conceptualization in visual form

In physics, chemistry, fluid dynamics, and other disciplines where no apparently "natural" (that is, no formally analogous) relation exists between images and observable phenomena, visual images are used to create representations of theoretical concepts. These visual images serve to constitute an idea of what a phenomenon–like an electron or subatomic particle–*is*, even though it doesn't necessarily have any inherently visual characteristics. Historians of science are keenly aware of the ways available means of visualizing help form the very nature of scientific inquiry.[15] Peter Galison has traced the tensions between two logical traditions–pictorial and computational–as dual parts of an epistemic practice that has structured much of the experimental activity of modern physics.[16] The laboratory apparatus of modern physics, he points out, particularly at the subatomic level, is used to create "images." Traces in a cloud chamber rendered visually give rise to an idea of a phenomena, affirming or undermining theoretical hypotheses. The form of such "traces" has a potent effect on the conceptualization of the phenomena.

The forms by which we understand the universe are to a great extent an expression of what we can imagine as the "universe of forms." [17] A lay person's example is conjured by the picture of the atom as a microcosmic solar system comprised of entities like little balls in orbit around a clustered nucleus. This mechanistic model blocks us from seeing the atom as an energy field whose particles are constituted as dynamic charges. Contemporary experimental chemistry makes use of visualization techniques for the design of molecular structures through visual manipulation–with analysis of the properties and behaviors following after. The techniques for experimental production of knowledge in the sciences are sustained by a belief that the visualizations have a correlation in a physical or chemical universe. One history of scientific thought is structured through a critical lens that focuses on the relations between ideas and their graphical expression.[18] In this sense we can invoke the concept of a graphical imaginary, that realm of ideological and cultural knowledge that is produced through symbolic systems.

Visual conventions for operations and procedures

Mathematics at first glance seems completely abstract and remote from visual morphology. But mathematics is shot through with graphical forms of knowledge production and representation. The columnar arrangement of numbers and linearity of equations operate through graphical principles–a fact quickly demonstrated if the familiar operations of addition or division are attempted on numbers that aren't arranged in the usual manner.[19] Higher level operations and manipulations of all kinds can be performed on numbers arranged in matrices and other formalized systems.[20] Geometrical figures are defined as graphical forms whose properties can also be described in equations.[21] Fundamental principles of set theory are figurative and visual, even if they can be represented as abstractions. The discrepancy between the mathematical description of intersections in set theory and the same information shown in a Venn diagram provides a dramatic example of the way a graphical image provides a visual aid to cognition. The specialized field of visual calculus engaged graphical methods to find solutions to complex problems in the age before computers were capable of automating such high-level procedures.[22] Vannevar Bush, one of the pioneers in conceptualizing computational operations, was trained in graphical mathematics and plotted curves to solve equations for engineering purposes.[23] Eugene Ferguson observed that the use of graphical means in design brought awareness of systemic flaws to the fore in ways that computational methods do not.[24] We should not trivialize these findings in the larger sphere of inquiry into the nature and function of epistemology.

The diagrammatic presentation of mathematical information depends on descriptive techniques at least as formalized and lacking in ambiguity as any natural language. The visual formalism of binary number systems–or decimals for that matter–is place specific. The linear order permits semantic value to register within the syntactic structure so that a 1 or a 0 represents any number of different quantities. Such apparently simple visual arrangements are governed by a strict syntax that provides a ground on which semantic meaning can be articulated. Much more can be and has been said about the rich intellectual relationship between visualization and scientific knowledge. Current work in shape grammars seek to describe graphical elements in terms of a limited rule set governing transformations. Process grammars attempt to recover the steps by which a shape has been achieved by analyzing its form as an outcome of a process.[25] These mark a shift from the descriptions of ways to crate formal entities in shape grammars to descriptions of shapes as the outcome of formalizable processes. [26]

Ultimately, my discussion will come to rest on an assertion that visual epistemology must be synthesized at the intersection of humanistic and scientific concepts of knowledge. Many of the conventions for representing statistical or theoretical information come from the sciences, so understanding these basic modes of relation – analogical, conceptual, and conventional – is fundamental to interpreting graphical expressions. But we have to consider the shift in intellectual ground that occurs when graphic forms are used in the humanities, where knowledge is only sometimes statistical, and far more likely to be derived from or concerned with interpretation. Self-reflexive critical models from the humanities are useful for looking at these graphic objects as interpretive forms no matter what field of knowledge is being represented visually.

Visual knowledge and the humanities

Humanists make use of graphical forms, though to a lesser degree than scientists, or so it appears if we include only the schematic and diagrammatic visual representations in our survey of habitual practices. Maps, graphs, charts, are part of the intellectual equipment of scholars of all stripes. We can expand that inventory to include a wide range of pictorial forms not usually thought of as "information graphics" -- namely the full corpus of images that constitute the objects of art historical inquiry and history of visual culture. Re-conceptualizing these as information forms is a useful exercise, for though regularly interpreted within the cultural trajectory, they are rarely examined for the ways their formal structures order information in a procedural sense. (Art historians are rarely interested in reading the syntactic structure of visual images as ways of organizing knowledge representation through graphical means.)[27] The history of imaging technology and analytic skills developed in response to the syntax of printed images are also foundational elements of the methodology of graphesis. The analysis of the specifics of inscription can be extended to a critical discussion of the rhetorics of visual forms and the intellectual assumptions structured into graphical relations. Finally, the cultural history of information graphics provides and essential insight into the authority accorded these expressions of statistical management and administration.

Information graphics in the humanities

Information graphics are useful in the humanities as well as in the sciences. Though the use of statistical methods and visualized display of data in the form of charts, graphs, or diagrams has been the exception rather than the rule in literary scholarship and criticism. Franco Moretti's recent arguments in support of visualization in the humanities are also arguments for the use of statistical analysis.[28] Charting the changes in publication patterns allows Moretti to make and support certain claims about the rise of the novel in a variety of geographical and temporal locations. These patterns are strikingly evident in the plotted charts that accompany his arguments. He focuses on the ways publishing patterns provide insights different from those that might be reached by reading an individual work. The condensation of information about several decades of activity into a single graphic demonstrates a basic principle of information design. Graphics are economical, efficient, and offer a way to grasp complex relations in an immediately legible form. But the methods by which they are composed (what information is measured and how) and the ways in which they are interpreted are often governed by statistical disciplines in which humanists lack expertise. A basic understanding of terms like average, median, and mean seems essential if the apparent authority of these graphics is to be subject to the same critical scrutiny habitually brought to bear on textual artifacts. Information can seem even more self-evident presented in a graph than in the disordered fields of inquiry from which the presentation arose. Concerns about interpretation at the level of defining data as well as understanding how to read conventional displays are part of the critical dialogue produced at the intersection of humanities concerns and computational methods.

Digital humanists have been exploring the value of statistical processing of textual information for decades.[29] Tools of visualization have been slower to materialize than those for producing word counts in corpus linguistics or work in stylometrics.[30] The difficulty of parameterizing textual documents is complicated – what should be called to attention through the techniques available for encoding search and analysis into text files, and how should these be used? What can be measured? Or marked in order to be measured?[31] The difficulty resides in getting over the threshold into a new approach to humanities study and beginning to think differently about how to conceptualize textual analysis and interpretation. Visual tools are as basic as interface and query windows, whose structures already shape the way researchers interact with electronic text collections.[32] But they can be far more sophisticated in their use of directed graphs, diagrams, scatter plots, tree structures, and other graphic methods of display.[33]

Perhaps the most dramatically overlooked graphical forms in the humanities are the most familiar: books, pages of print, letterforms, and all the structures of textual and paratextual apparatus.[34] The graphical features of texts are generally regarded as trivial, except by students of bibliography, book history, or design.[35] But basic codes for reading are graphically structured. The conventions of text and commentary in marginalia, of justification and documentation in footnotes, or even the schematic shape of a table of contents are graphical ones. These organize our reading and provide a means of using the text. A system as fundamental as page numbers is a means of manipulation that functions through graphical means. At an even more fundamental level, we can understand that white space is constituted in its relation to letters and text layout through dynamics of a system of graphical co-dependence.[36] Page space isn't a given, an a priori static entity, any more than a gutter, margin, or column. They are all elements of a system in which dynamic tensions work within a system of differential values. A margin isn't an inert space, but a field of defining tension between text and page edge, and exerts a graphical force in relation to other elements on the page. Even if the idea that a book is an information system is somewhat familiar, understanding how it operates as a graphical system through a set of procedural codes is less so. Thinking about the structure and operation of the visual features of textual artifacts is an important aspect of graphesis–especially since the rhetorical effect of these codes is so frequently overlooked.

Expanding the inventory and methodology

We can extend the study of graphical forms within humanities fields to include the works that comprise the history of art, as well as works of popular and commercial culture. The traditional methods of art historical study provide their own intellectual foundation for the critical apprehension of graphical forms through iconographical study, formal analysis, theoretical methods, and cultural studies.[37] But the traditional study of visual images in the humanities largely focuses on works of art for their imaginative and aesthetic properties and their place within and as indicators of cultural and social history. Portraits and landscapes, still life images and genre scenes, are not generally classified as "information" graphics or studied for the epistemological principles they inscribe.[38] And MRIs, electron micrographs, or statistical tables are only occasionally counted as art works. Once in a while a museum will exhibit scientific images that can be appreciated for their aesthetic qualities -- with a disclaimer not to worry about understanding the actual content of what is depicted (!) meant to set aside the anxieties of viewers not conversant with the technical knowledge of the scientific field.[39] Well-intentioned but short-sighted, such formalist premises make it even more difficult to return a critical gaze to traditional pictorial images and look at them as *information*. We are made to believe that the orders of information-bearing graphic images are different from aesthetic ones, and vice versa. Such habits of thought blind us to many of the structuring principles, as well as rhetorical operations, of images on both sides of this (to my mind artificial) divide.

James Elkins's interpretation of visual information across disciplinary categories has addressed these distinctions directly. His inquiry into what pictures "are" explores the enormous variety of non-art images for their expressive qualities, demonstrating the effect of aesthetic qualities on the communicative operation of medical and scientific imagery.[40] Art historians are rarely interested in the discussion of graphical forms such as design images, information graphics, or other visual materials outside the canon. A small subset of works in the history of nature illustration or scientific images exists at the margins of art history.[41] Even among historians of graphic design, information graphics are a marginal topic.

The history of perspective and representation of space encode the subjective position of a viewer in their schemes.[42] The metacritical language for describing the way these systems work defines dynamic principles functioning in all images (every image is produced from some point of view or standing point). Seeing a landscape and its legible but complex logic as a way of ordering and organizing information emphasizes its structure as a knowledge system rather than a representation or illusion. The specialized principles of composition, proportion, dynamism, and precepts of classical design in drawing and design are evidence of rationalized knowledge systems put into practice, even if they are not usually addressed as such. We have to cast an oblique eye at art historical works and studies in order to make them show off their epistemological assumptions. Once we do so, however, we grasp immediately the extent to which such imagery is fundamental to the inquiry into the epistemological function of graphic forms of all kinds. How we know what we know is predicated on the models of knowing that mediate our experience by providing conceptual schema or processing experience into form.

Imaging technologies

The study of imaging technologies provides insights into the cultural history of graphic media as well as the information-bearing characteristics of visual communication. The landmark study of William Ivins referred to above, and that of his outstanding student Estelle Jussim, provided a foundation for the study of printed images and their cultural impact.[43] Both focused on articulating the interrelationship of graphic expression and content by calling attention to the specific properties of mark-making. Addressing the inscriptional codes of which images are composed at the most fundamental level, they provide the foundation on which distinctions among photographic, graphic, electronic, and digital images can be developed. Issues of labor, skill, edition size and distribution, costs and reproducibility are linked to the specific means by which images are produced. The "visual communication" Ivins refers to is embodied rather than vehicular. His use of the term "syntax" calls attention to the systematic rules that govern mark-making such that images are structured according to conventions and constraints within a particular medium.

Such analyses are not deterministic. Ivins doesn't assume that a particular method of making produces a particular response, but he does provide the descriptive acuity by which to describe visual effects. The trained eye can read image structure, but also, production history, by distinguishing different kinds of marks, lines, tonal values, color ranges, densities, textures, and patterns. The surface of currency, raised ink lines left from an intaglio plate, has a graphical-tactile character that is essential to its operation. Visual translation from one medium to another always reveals the effects of transmission, the graphical code that literally inscribes knowledge. Ivins's passionate dislike of the ultra-rational technique of steel engraving is a dramatic instance of the affective power of image technology.[44] Extreme cases always show the rule -- the softening effects of paint on black velvet can render the most rigorous image kitsch, and the use of a medium can create cognitive dissonance simply by force of the rendering.

Critical methods for reading the rhetoric and logic of graphical forms

Analytic tools from humanities scholarship shed light on the critical history of graphical forms and to expose the assumptions on which such images are created. Tracing the historical source of image types such grids, tree-structures, pie charts, maps place their rhetorical forms within a broader intellectual history. In every case, their presentation of information creates a form that is already an argument. Graphic schema create syntactic structures within which semantic values can be assigned and maintained. We can read the organizing syntax of these graphic structures. The structured relations among information elements is as much an expression of a way of thinking as any other intellectual form. To put it another way, graphical structures are rhetorical arguments.

But though forms in which statistical information is codified express assumptions about knowledge through their logical structure, these assumptions are not necessarily self-evident. Each also has its origins in particular disciplines whose needs it served and whose intellectual attitudes it embodies.[45] The inventory of types of visual information structures isn't long: bar diagrams, trees, maps, pictorial diagrams and icons, flow charts, and tables. Taking each of these in turn we see that:

- Bar diagrams derive from statistical analysis and function through supposedly unambiguous distinctions expressed in a grid of rationalized information readily available for comparison according to a standard metric.
- Tree structures, by contrast, derive from genealogy and evolutionary biology and suggest continuity of dependence and kinship in the flow of information across generations.
- Maps are the record of explorations, phatic and tactile, narrative and immersive when created from inside the experience of discovery, but rationalized through projection when produced from outside, as images. The complexities of representing a curved form on a flat surface, as well as the many cultural imperialisms at work, provide their own history within the range of projection methods.
- Pictorial diagrams that make use of icons and other images have a cultural specificity through their particular details, the way they are rendered, as well as the inventory of images used (to show a woman, for instance).
- Flow charts have their origins in management and organizational structures. The directional force of power relations and movement of goods through a production system often have a conspicuous absence of human agents, as if processes were an inevitable and natural fact.
- Tables and grids work by putting discrete cells of information into meaningful syntactic relations with each other -- a classic example is the timetable.

These forms all exist on a single, flat surface, and are common features of written, inscriptional, and print culture.[46] But more complex spatialized and temporalized relations can also be described through topological and topographical approaches. Johann Benedict

Listing, in 1847, was the first to use the word topology to discuss the connectivity of surfaces. Leonard Euler's struggles with the Konigsberg Bridge problem in 1736 established what he called a "geometry of position, not of measure" as a foundational principle. [47]

The topological vocabulary describing entities and relations is also applicable to textual structures and the para-textual apparatus of marginalia, footnotes, margins, columns, headers, footers, in a way that is brought into sharp focus in a digital environment. Theories of editing that engage with continuity and discontinuity become an additional aid in reading the rhetorical operations of hyperlinked environments.[48] The act of reading electronic documents only extends the actions that comprise readings in print culture. Attention to reading on the screen takes us back to a fresh awareness of the ways we can read in a print environment. In both instances, the graphical forms that express relations and provide clues to reading are part of the "information" of the text.

All graphical schema are built on the single principle of defining entities and their relations. But the characteristics by which the entities are defined and the specific ordering of relations quickly escalate to complexity, even when the primitives are simple. We have only to extrapolate from Boolean algebra to the figurative form of an integrated circuit to understand how quickly a set of flows and gates can be connected into a complex figure through use of the relations AND, OR, and NOT.

Cultural history and mathesis

The cultural authority attached to graphic images used to represent knowledge in the sciences undergoes a radical transformation when the assumptions about statistical methods are transferred to an administrative domain. The instrumental use towards specific ends and tasks that characterizes bureaucratic adoption of statistical methods and their graphic representation shifts the management of information from an intellectual to a political sphere. We can discern the ideological aspect of any scientific inquiry, but the applied use of information management makes use of the cultural authority in statistical graphics in a way that exceeds the qualified reservations of scientific method. When Gaspard de Prony computed a new organizational structure for Napoleon to calculate taxes and track the citizenry, policy and control -- not self-conscious critical reflection on the nature of knowledge -- were foremost.[49] The 18th-century sensibility that underpins the work of William Playfair, commonly regarded as the producer of the first statistical graphs, expresses as a managerial attitude towards information that participates in the broader creation of administered culture. Rationalization and its effective implementation require such management. Human cultures have made use of calendars, grids, tables, and other organizing structures for the presentation of information since the earliest civilizations arose in Mesopotamia, where they also served to create systems of accounting and record-keeping. But the shift in scale towards modern bureaucracy enabled and required by industrial transformations certainly increased the use and frequency of statistical graphics.

The concept of mathesis is older, and has its origins in the chimerical search for a way to "dis-ambiguate" (borrowing a term with much currency in the digital humanities) the processes of human thought and standardize the representation of thinking and of knowledge in systematic codes.[50] Descartes is credited with the first use of the word mathesis (and with the first use of x and y coordinates), defined as the belief that all knowledge might be represented with the same degree of logical stability that operates in mathematics. Philosophical speculations on the concept of numbers as a set of transcendent universals, primitives for the values that comprise all entities and relations, can be traced into obscure antiquity. But the forward trajectory from Descartes into the modern period intertwines the concept of mathesis with the development of formal logic and aids in the foundation of computing. Early theories of artificial intelligence, premised on a belief in the programmable nature of thought, borrowed their faith from this long tradition. The ambiguous character of visual forms, with their infinite variety and high degree of specificity in each instantiation, puts them at odds with the stable bases on which mathesis presumes to stake its knowledge claims. In discussing the cultural authority of information graphics, mathesis and the applied use of statistics should be held in mind as the target of critical discussion (rather than empirical methods within the sciences).

As graphical forms, particularly charts, diagrams and tables, become instrumental to the functional administration of information in the 18th century, they participate in the emergence of social sciences, where they provide authority to analysis of cultural phenomena. The objectification of information reinforces a highly mechanistic distinction between subject and object. Data are presumed to reside in a stable, quantifiable, observable universe. The observer assumes that the data have an a priori existence, independent of observation. Statisticians are particularly astute at the double game of using and qualifying their methods in one and the same gesture. They acknowledge the rhetorical nature of graphical form. But the administration of census data, demographic information, and other social factors continues to be processed through standard metrics of information collection that served as the basis of empirical sciences more than two hundred years ago. Recognizing the historical relationship between 18th century systems of management and the use of information graphics provides a useful corrective. Information does not exist in a natural state, available to the light of reason in the form of knowledge ordered to display itself in a self-evident way. Not at all. The critical history of graphical forms of information display has the task of exposing these "natural" assumptions about knowledge and the way it is constituted in graphical form.

Taking apart the history of graphical forms to elaborate the assumptions that reside in their use and operation as part of modern systems of administration based on faith in empiricism, reason, logic, and statistics is a task to which the humanities scholar is well suited. This investigation can be cast under the general heading of a cultural history of graphical forms of information. It proceeds with full recognition of the contributions of post-structuralist criticisms of reason, truth, and grand narratives and with the insights of French critical theory as a basis for an understanding of the "disciplinary regimes" of rational systems.[51] Crucial concepts include the nature of narrativity, the rhetorical force of expression, the content of form, and the cultural hegemony of models of knowledge that naturalize their own instrumental operation. Starting with these concepts well in mind allows us to leap-frog beyond the important, pioneering work of Martin Gardner in his study of diagrams (one of the still-outstanding contributions to this small field). This critical foundation also puts my approach to graphesis in a tense, even oppositional relation to that of such cheerful information designers as the estimable, but unrepentantly empirical, Richard Saul Wurman, the more severely orthodox Edward Tufte, or the pragmatic functionalism of Ben Shneiderman.[52] Their work contributes to the history and display of visual epistemology, but stops short of conceptualizing a theory of graphesis. To do that we have to combine the historical, critically informed analysis of graphical forms with current theories of knowledge from both humanities and sciences. A brief look at sources within information design and the history of graphic design and its theorists provides another illuminating set of perspectives on this larger task.

Information Design and Graphic Design

Information design is a subset of graphic design. In the words of one its foremost practitioners, Edward Tufte, the task of the information designer is to "show the data" and to "avoid distorting what the data have to say."[53] Or is it? Tufte also goes on to say that, "Graphics *reveal* data." The conviction that information exists outside of –or in advance of – the presentation of data in graphical form is problematic, even inaccurate, from both a theoretical and a practical point of view. On a mundane level, certainly we can understand that information designers see their task as the creation of clear, legible, unambiguous presentations of data. But every graphic representation is a rhetorical device. Every presentation structures arguments -- it doesn't "reveal" facts in all their purity through the fallible, flawed system of graphical expressions. The relations between *what* is communicated and *how* have to be acknowledged.

Since the principles of information graphics have been distilled from larger projects in the history of graphic communication and the systematic study of visual form in the arts and design fields, we can survey them for exemplary works of formal systematization. These take visual and verbal forms. Many practitioners and theorists have created an approach to the "language" of visual form. Their work has contributed to the study of graphic variables, gestalt principles, and other elaborations of primitive elements and operations of graphical systems. These fundamentals provide a useful starting point from which to return to the larger questions raised by information graphics.

Languages of form, graphic variables, gestalt principles

In the 20th century efforts to create a fully formalized system for describing graphical form came from visual artists, designers, teachers, researchers in the psychology of perception, semiologists, and theorists working to articulate a systematic understanding of graphic communication.

In the 1920s, contemporary with the more general linguistic turn in philosophy, the trope of language emerged as a model for vision.[54] Scientific models of systematic thought had risen to prominence in analytic logic. Descartes' dream of mathesis and Leibniz's quest for a rational calculus had served as inspiration for the 19th-century mathematician George Boole. His *Laws of Thought* belongs in the history of logic and computation, but also in the history of intellectual tendencies that manifest across the humanities and social sciences. The work of artists and designers in the German Bauhaus, Dutch design, Russian and new Soviet institutions of technical learning such as Vkhutemas, were expressions of a broader general belief in logical, universal structures. Natural language and logical language are subject to a productive philosophical dialogue in this period, traceable in the major shifts in the work of Ludwig Wittgenstein.

So when we note that "the language of visual form" is a phrase that became current in the early 1900s, it should be recognized that the impetus towards this project comes from a broader cultural sensibility. This phrase serves as the basis of foundation courses in graphic communication today, tracing their roots to the Bauhaus curriculum with its systemic approach of visual literacy, primers and manuals. By their attempt at systematicity, they provide useful inventory of formal features and properties. Wassily Kandinsky, Laszlo

Moholy-Nagy, and Paul Klee provide richly suggestive discussions of the dynamic principles of visual form. Kandinsky's 1926 publication, *Point and Line to Plane*, clearly shows the influence of late 19th-century Symbolist synaesthesia. But it also exhibits the drive towards systematic formalization that was characteristic of the modern, Bauhaus sensibility. Written from notes originally sketched in 1914, Kandinsky's work is a unique creative analysis of visualization. Kandinsky understood vision as a special instance of more universal theories of proportion, harmony, number. Image and sound were correlates in his system, and the provocative language of his work, combined with its step by step analysis of the properties of points, lines, and planes, remains useful, if idiosyncratic.

Perhaps most useful is Kandinsky's willingness to isolate a set of primitives of visual composition that are not linked to figurative or literal references. Thus the point is the "proto-element" in his system while the dynamism of lines as forces describes rules that are simultaneously concrete and abstract. Kandinsky's conviction that principles of design crossed the boundaries of media and disciplines kept his vocabulary schematic. Though apt for discussion of visual compositions, it has a logical structure that is independent of specific visual properties. For instance, in talking of lines, he describes principles of rhythm in terms of repetition, distinguishing quantitative and qualitative aspects of reinforcement that may be achieved in the process. Given the period in which he was working the language of the 4th-dimension shows as the words waves and potentialities appear with equal fluency among other figures of dynamism. His closing "Goal of Theory" to make "pulsation perceptible" and determine "wherein the living conforms to law" is striking in its openness to experience in advance of system.[55] One senses Kandinsky charting the course of his own awareness as a systematic inquiry in order to discover the dynamic laws of formal dynamism.

Kandinsky's influence, along with that of Klee (particularly his notebooks and sketchbook texts) is also evident in the writings of Bauhaus artist Moholy-Nagy. *The New Vision* (first published in 1930) and *Vision in Motion* (1947), establish curricular and professional guidelines for design practice. Moholy-Nagy's institutional shift to the New Bauhaus in Chicago helped bring the European-based precepts into an American curriculum where they helped form the principles for "foundation" classes in art and design schools for decades. Josef Albers, another key Bauhaus figure, performed his own rigorous research into the rules by which color functions in relations and published this for use in pedagogical and professional practice. The list could be expanded here to include the designers in various early 20th century avant-garde movements who helped formalize radical experimentation into a modern idiom, such as El Lissitsky, Piet Zwart, and Jan Tschichold. Filmmakers Dziga Vertov and Sergei Eisenstein discussed editing techniques in film to formalize the ways montage worked through sequences of visual images, across cuts, and within the composition of individual images. Their pioneering work established basic principles of film editing.

These texts of early 20th-century designers-turned-teachers or practitioner-theorists became the basis on which the teaching of graphic design was shaped. Distilled into a set of principles that can be used to create effective communication in visual form. Georgy Kepes's *Language of Vision* (first published in 1944), is far more pragmatic than Kandinksy's spiritual science. "Plastic organization" and "Visual representation," the titles of the two major divisions of his book, though general are rooted in application to concrete image-making. Armin Hoffmann and other designers writing texts with titles that include phrases like "principles of graphic communication" elaborate tenets of formal visualization as compositional principles (size, scale, movement, order, symmetry, asymmetry, etc.).

By the 1950s, it was commonplace to refer to "graphical language" or "visual communication" as if the comparison were completely natural. In 1973, Donis A. Dondis's classic *Primer of Visual Literacy* contains chapter headings like "The basic elements of visual communication" and "The anatomy of a visual message." The text describes ways that "stress" and "repose" or "levelling" and "sharpening" –among dozens of other characteristics–are attributes of visual systems that can be identified, learned, and made use of in a controlled manner. These properties come to seem self-evident as a result, and the assumption that they inhere in a graphical object goes unquestioned. This development is paralleled by an absorption of the once-radical innovations of avant-garde asymmetrical typography and streamlined modern design into corporate information systems. The radical roots are lost. The utopian dream of epistemological defamiliarization through innovative design dissappeared as the price of success.

An impulse towards logical formalization connects these studies to the semiotics of visual images. Charles Peirce described the logical structure of signification in his paper, "Logic as Semiotic."[56] He also created a complex system of existential graphs to perform his logical research operations Peirce's use of graphical means to represent and compute complex logical relationships depend on the capacity of images to communicate relations of containment, dependency, hierarchy, and transformation. Peirce's system is highly abstract, even if it can be used to describe concrete objects or relations. Notation systems in formal logic, like mathematical symbols, are graphical and abstract. Early semiotics created structuralist principles to organize descriptive systems for understanding narrative, folklore, clothing, visual arts, and poetry, using language (often formal models of language) as the model. Among Prague school semioticians active in the1930s, Jan Mukarovsky, Jiri Veltrusky, Roman Jakobson and others extended these discussion to carefully studied distinctions between visual and verbal art-forms.[57] Attention to the aesthetic features of form and to the cultural conditions of their use and effect extended the legacy of earlier Russian formalists and their contemporaries studying language and literature, but made a more explicit connection to the analysis of visual imagery and other cultural sign systems.

These early 20th-century semioticians had a direct influence on Roland Barthes, who then provided a conduit through which that earlier formalist approach was given a substantial role in the semiotic analysis of photography, film, advertising, fine art and design images.[58] Jacques Bertin's exhaustive work on the semiology of maps established a vocabulary for graphic fundamentals (shape, texture, color, size, orientation, placement, tonal value).[59] This in turn has proved useful for pioneers in artificial vision and robotic sight. The work of the late David Marr broke new ground through such syntheses, and defined visual primitives in terms of the operations through which each property can be processed. Marr showed that different features of a single image could be isolated and described independently, so that attributes like texture or color were separated from shape or orientation.[60] The task of attempting to build an artificial means of processing visual stimuli into usable form extends earlier formal descriptions. But merely listing visual elements, attributes, and behaviors seems only partially adequate to a task with so much dependence on embodied experience and life-world knowledge.

All this may seem like a long way from graphic design, but the efforts to create a stable formal system of description -- and a corresponding visual inventory -- for understanding and then using graphic communication cut across many fields. Gestalt psychologist Max Wertheimer, working in Germany in the 1930s, discovered that certain principles governed the processing of visual phenomena into patterns of cognitive perception.[61] These gestalt rules of proximity, closure, similarity, and continuity were governed by the way the eye grouped objects, followed cues about direction, and read properties of shape, tone, or orientation. Functionalist to an almost mechanistic degree, the gestalt approach provided a useful language of description within which the formal tendencies of image processing can be understood. But formalizing these into algorithmic principles in a step-by-step rule set has shown how elusive the determination of rules governing human visual activity actually are. The rule sets are not only complex, but emergent, and depend upon tasks, drives, and circumstances to shape the way communication between eye and mind process stimuli.

Alan MacEachren's highly synthetic, *How Maps Work* (a book whose title is deceptively simple) takes up earlier formalist precepts and advances them through a dialogue with contemporary theories of epistemology.[62] Formalized analysis, semiotics and a logical description of graphical fundamentals or primaries as well as rules for their processing by human perception and in a more abstract sense, as information, are clearly the legacy of interdisciplinary investigations. Whether they lead to the creation of a dynamic system of co-dependent variables depends on attitudes towards epistemology and visual experience.

Many of these formal, logical systems turn out to be based on assumptions that are relevant to a critical approach to information graphics.

Information graphics

Much can be said about the way visualization provides ways to represent large amounts of complex information to show patterns across substantial amounts of data that would otherwise appear as numbers. And of course, much has. Edward Tufte's work stands out in this field. *The Visual Display of Quantitative Information, Envisioning Information,* and *Visual Explanations* are striking demonstrations of the principles of elegant graphic communication he espouses. Tufte's work exemplifies the use of design principles at the service of statistical information. As indicated above, Tufte shares with the more mundane brethren who create charts, graphs, and diagrams certain assumptions about the nature of the data with which he works and the task of the designer in communicating this information in visual form. The information is gathered with standard metrics. The assumption is not only that the data pre-exists the graphical presentation, but that the data have an absolute identity outside of their representation. The task of the designer is to make as accurate a representation of that information as possible.

Closing the gap between information and presentation as tightly as possible is the presumed task under these circumstances. Lurking Platonic idealisms shoot through this approach, suggesting that statistical information already has a form, and that the task of material presentation is to embody it in as close to perfect an image as human fallibility and crude figurings forth in matter can manage.

Tufte is keenly aware of the rhetorical force of presentation. One of his most compelling examples is the one in which he discusses the way crucial information about the Challenger spacecraft was misleadingly presented in a graphic which, had it been properly designed, might have altered the fatal outcome. But he is a hard-boiled empiricist at heart. No postmodern, deconstructive critique of the tenets of truth come whimpering through his wellregulated domains, and no sense that he makes the information by making its image qualifies his assertions of accuracy. If Thom was blind to the virtues and service of graphical forms, Tufte is speechless with regard to the profound critiques of empirical method with which scientific activity has long measured its own intellectual distance from naïve truth claims.

But the cultural history of information graphics, diagrams, maps, charts, and other schematic images, is a rich field to mine for productive models within the horizon of the theoretical tools provided by the humanities. Paul Mijksenaar's *Visual Function: An Introduction to Information Design* presents information in the context of activity.[63] All information graphics *do something*, Mijksenaar suggests. They organize the possibility of use, of interaction, and by doing so, intertwine form and function in sometimes subtle, sometimes deviously deceptive, and often highly effective ways. The emphasis on the way graphics function within a system of mediated exchanges with human users brings information design closer to its cousin, interface design. A language of usability, rather than compositional form, has appeared in parallel with the growth of graphical user interfaces and the realization that their design principles give the lie to the static nature of print artifacts. Books and graphics, after all, are interfaces through which readers interact with a document to produce a text.

Information graphics are not only instrumental, useful for the efficient and effective presentation of dense amounts of data. They are historical artifacts themselves, filled with interesting incidental and substantive information embodied in their production, style, and graphical properties. But perhaps more important, they are expressions of procedures for generating knowledge through the act of visualization and ways of displaying knowledge embodied in visual imagery. They are governed by a straightforward set of analytic principles, as discussed above: the hierarchical structure of classification using trees, the rationalized nature of grids and tables, the implied sequence of tabular data, the connotative use of color and shading, and so on. Many information graphics have their origins in the sciences where a representation is conceived as a surrogate, a necessary means (form of communication) towards a desired end (presentation of information). Others are produced in the worlds of commerce and business, government administration and bureaucratic environments where they serve to create "natural" images of highly constructed knowledge. But others derive from ways of using images to learn something previously unknown, as in plotting data to discover patterns or calculate outcomes.

Visualization methods used in computing

Computational processing of data into visual form is a specialized field of information graphics.These methods involve processes of data transformation and are created with specific uses in mind that shape the data and their display.Visualization methods as models of operations performed on data provide five distinct methods of algorithmical interpretation:

- A descriptive presentation of already known data in a visual form allows patterns of large quantities information to be seen and understood. The quantitative processing of massive amounts of information, supporting a quantum leap of qualitative judgment. (Show the comparative length of Shakespeare's plays and the number of major and minor characters in each.)
- Analytic visualization allows for querying of data to see if it meets certain conditions, displaying those sets of information that conform to the parameters of the

query. Data, already present, can be analyzed and visualized. (How many of Rossetti's double works written during a specified time period were exhibited in a particular circumstance.)

- Modelling in visual form allows a hypothesis to be tested through visual means. (A molecule in a certain form exhibits particular characteristics, if another chemical substance is forced into that configuration, then what properties does it exhibit. The same procedure could be performed on an aesthetic artifact according to parameters of formal structure of meter, rhyme, narrative, semantics, word frequency etc.
- Procedural visualization begins with an algorithm that puts a process into place from which a form is created through a series of evolutions. (Process driven works of literature use such methods to create works from, for instance, vocabulary lists and rules for their combination. Permutational and combinatory work falls into this category.)
- Developmental and mutating procedural modes allow the algorithm to self-modify according to criteria of selection that simulate evolutionary models. (The rules of the procedure modify themselves so that not only the forms, but the terms on which they are created, continue to change.)

These operations are used for data manipulation and can be applied to texts as generative and analytic processes. In fact, we can argue that they are already used in interpretive practices, simply not in this explicit form.

To fully explore the idea of graphesis as a means of producing interpretation, new knowledge from a subjective point of view, we need to extend the concept of epistemology. We have to go beyond thinking of knowledge in terms of mechanistic and static relations in which things known and things shown are assumed to be independent entities operating in an objective universe of phenomena existing in advance of their apperception. Visual epistemology is based on a more radical theory of knowledge. The radical concept of subjectivity, and of the co-dependent nature of knowledge and interpretation, have been integral to quantum physics for nearly a century and to cognitive studies for half that long. Graphesis takes these concepts as foundational and uses them to construct a theory of knowledge through attention to the graphical forms of its many expressions.

Vision, Cognition, and Subjectivity

Theories of artificial intelligence track the development in concepts of what it means to know and learn. Through the latter half of the 20th century, these theoretical discussions exhibit a succession of claims, each of which had its limitations exposed as computer scientists and robotics engineers attempted to create machines that could "think."[64] Top down programming, bottom up neural networks, embodied approaches to knowledge and the construction of artificial life forms present a fascinating study. The development of cognitive studies synthesizes concepts from systems theory and the psychological strain of thought known as radical constructivism. The work of Umberto Maturana and Franceso Varela, this approach conceives of organisms as autopoetic systems whose capabilities emerge in a co-dependent relation with their environment, not independent of it.[65] This approach dispenses with notions of autonomy as untenable, making an entity and its context mutually defining in relation to a border that marks their distinction. Ernst von Glasersfeld's work in radical constructivism suggests that human cognition emerges dynamically in a relationship of exchange between physiological capabilities and circumstantial stimulation in a continually mutating system.

Synthetic approaches to the problem of knowledge also draw on complexity theory for models of emergent behavior and of intelligence as, possibly, an emergent property. These rubrics signal a contemporary approach to knowledge from various fields that converge in the current moment to shape the ways we can think about graphesis. These stand as markers, evoking a general theory of subjectivity as crucial to our current conception of knowledge. Without them, graphical knowledge production and representation in the humanities -- in any field -- will remain locked into mechanistic models of thought in which an image is "out there" and an eye brings it "into" the mind. The realization that an image, like a text or any other document, is produced as a reading, as an act of interpretation that arises between a reader/viewer and the image/text, shifts this conception.

The recognition of subjectivity has a humanistic and a scientific history that are also crucial to any contemporary formulation of knowledge -- and to its visual production and representation. By subjectivity I don't simply mean the expression or inscription of individual idiosyncracy, the marks of taste, character, or personality that differentiate one person's version of experience from another's. Subjectivity is a structuring principle, not just an inflection, and refers to the place of the observer within the phenomena when these are conceived as a dynamic, co-dependent system. Curiously, these concepts have taken root in physics and the sciences more rapidly than in the humanities.

In the early 20th century the ground shifted from the objective, empirically based concepts of physics grounded in mechanistic, Newtonian models. Quantum physics and principles of uncertainty characterized a radical change in the ways the observer and observed phenomena are understood, collapsing the two into a dynamic system. Rather than imagine discrete phenomena available for observation, or the subject-object relationship as a dialogue between two independent entities, the quantum theorist suggests that phenomena arise when an observer intervenes in a field of potentialities.

Psychological theories of radical constructivism, cognitive studies, provide their own disciplinary frameworks of a dynamic and relational, systems-based and emergent, concept of knowledge that is as far from naïve empiricism as Heisenberg's uncertainty is from Cartesian rationalism and Newtonian physics. Jerome McGann has sketched this theoretical intersection in his "Texts in N-Dimensions" and elsewhere.[66] His anti-vehicular approach to texts combines with theories of knowledge and cognition that makes use of quantum theory within interpretive practice and the study of texts.

The tenets of graphesis I am promoting are aligned with the precepts on which McGann proposes interpretation as fundamental to the production of a text. Graphesis is premised on the idea that an image, like a text, is an aesthetic provocation, a field of potentialities, in which a viewer intervenes. Knowledge is not transferred, revealed, or perceived, but is created through a dynamic process. Epistemology describes a way of knowing, not static knowledge. With this in mind, we can return to the final sections and describe ways to use graphical form for the self-concious creation of knowledge.

Concept Modelling in Visual Form

In the sciences, visual modeling techniques are frequently used as a way to test a thesis or create new knowledge through experiments that bring an idea into form. Visual modeling techniques and procedures are rarely used in humanistic approaches to interpretation. In part this is because our work tends to be text-based and determining what is to be "quantized" in a text is sometimes difficult. The rise of information design and increased familiarity with display techniques as part of computational analysis in digital humanities has softened the resistance to visual presentation of data. But approaches to interpretation that use visual modeling as primary methods of analysis, to create the data, not just display it, are less familiar.

How can we understand the relation of representation and model? All visual images are models, if by model we mean an abstract, schematic structure that expresses a concept. Representations appear to be self-evident, but we can qualify this by showing that a representation is a special type of model. Representations exhibit different degrees of isomorphic connection between the visual image and its referent (Charles Peirce's categories of icon, index, and symbol), but even the most visually analogous image (e.g. a realistic rendering of a frog) is a model (in this case, it expresses the concept of visual analogy and isomorphism).

Even the earliest graphical expressions of human activity demonstrate basic principles that remain operative in current forms. A Neolithic calendar found in Bulgaria and dated to the 4th or 5th millennium BCE uses a grid to organize the signs tracking the phases of the moon. A high degree of abstraction is required to create a structured system to conceive of temporal events in such elaborate relations. Calendars are visual forms designed for use, not static display.[67]

In another example, a Babylonian calendar can be understood as a surface organized to put temporal units into relations with each other in a very specific way. The surface has been rationalized, organized by a system of coordinates that structure information so that we read it relationally. But in fact, the abstract structure isn't a representation of time, it is a model of time that allows for computation. The structure and the information are not identical with each other. This calendar models temporal elements so they can be manipulated-- it doesn't just represent some "natural" condition of time. By providing an idea of the way time is structured it embodies this in the graphical presentation, but the schematic abstraction allows different combinatory possibilities to be produced. The calendar grid suggests that the days have both an ordered sequence and are part of grouped and repeating events -- ideas that are readily apparent in the visible evidence. Similarly abstract capabilities are evident in the tokens devised in the earliest counting and accounting systems, and the principles that organize cuneiform writing in the 3rd millenium BCE make use of numbers, symbols, and word-representations simultaneously. A mark doesn't represent some thing in such a system, it represents an instance of a type of thing within categories the classification system for which is nowhere rendered explicit but is nonetheless fully operative in the graphical code. Kind of amazing.

The distinction between model and representation allows for self-consciousness about the rhetoric of graphical expressions that demonstrate the capacity of visual work to generate new intellectual insight, not simply represent what is already known in a graphical form. Basic distinctions need to be clarified between concepts of modeling knowledge and representing it. Representations are always premised on abstract conceptual schemes–or models–that shape any individual expression within constraints and patterns of thought–even as that realization provides a crucial insight for breaking through existing habits. Our ideas of what something should be -- a house, an airplane, an automobile–constrains our ability to design these things within an abstract model. Breakthroughs in knowledge come from changing the model, or by innovative expressions. Changing uses of computer aided design have signaled a shift in attitudes towards architecture and the manipulation of forms through abstract, graphic processes.

Graphical Interpretation

I want to end with a discussion of two examples of the use of visual methods in the practice of interpretation. Though we know visual images embody interpretative assumptions, the idea that graphical means can provide an interpretation, be used as tools in the subjective interrogation of texts or other objects, is less familiar.

Ernst Fraenkel's graphical studies of that most resistant of poetic objects, Stéphane Mallarme's *Un Coup de Des* is a rather unique, and even bizarre, instance of graphical interpretation.[68] In a series of drawings Fraenkel discovered relations among the semantic and graphic elements in Mallarme's text. He created a vocabulary of constellationary symbols, ways of grouping elements in the text, patterns and shapes to call attention to and analyse hierarchy of language and form, and a whole host of other techniques. By literally drawing his reading of Mallarme's text, Fraenkel created drawings as interpretative acts. The new set of images is accompanied by a textual gloss. The diagrammatic charts have a range of connect-thedots, surround-the-serifs, isolate-word-groups, and other methods of chunking and emphasizing the intersection of semantic and graphic structures. Striking to the eye, they are also non-standard and idioscyncratic. But Fraenkel's experiment in discovering the "unconscious" structures of this poetical enigma through graphic analysis is an exemplary demonstration. It remains one of the unique instances of employing graphical means to show something about the ways we read an imaginative work and produce it as an interpreted text through that act of reading. We could point to the use of techniques like cognitive mapping that also rely on visual means to create understanding, and situate Fraenkel's work within that sphere. From that perspective, we understand textual interpretation as an act of cognition, of coming to know through a process of dialogic exchange in a codependent relation of subject and object.

My other example is my ongoing, in-progress work "Subjective Meteorology." This has a relation to an earlier project done in collaboration with Bethany Nowviskie, "Temporal Modeling," in which we developed a graphical language to model the complex temporalities in humanities documents and research.[69] By contrast to the linear, homogeneous, and continuous models of time that are used as standard metrics in empirical sciences, we sought to create a system that would embody the subjective experience of temporality. Thus we worked on a graphical system to model the multi-linear (forking paths), heterogeneous (varied in density, rate, and scale), and discontinuous (broken, repetitive) temporalities that are part of human experience, and certainly featured in aesthetic and historical texts. Subjective meteorology makes use of the metaphors and templates of weather to create a graphical system for charting the dynamics of personal experience. All of these are modelling systems, not representational systems. They are all concerned with generating new knowledge through the use of visual means, not assuming that knowledge exists a priori.

Conclusion

Graphesis is concerned with the study of visual epistemology as a dynamic, subjective process. It takes as its objects of study the history of visual forms, graphical expressions, and the concepts they embody within a social, cultural history. It seeks to expose and describe the principles for structuring knowledge through graphical form. It examines imaging technologies as instruments whose inscriptional characteristics register informationally, and also seeks to discover the ways various typologies of form have structured systems of graphical communication, artificial vision, and computational modeling of information in graphical display. Finally, graphesis is concerned with the creation of methods of interpretation that are generative and iterative, capable of producing new knowledge through the aesthetic provocation of graphical expressions.

As the use of graphics intensifies, as it has with the use of display capabilities built into computers from palm and desktop models to major research engines and special effects factories, graphical knowledge seems like a topic whose time has come. Am I leaving you with grotesquely exaggerated claims for the possibilities of expanding our understanding of knowledge through a critical discussion of graphical expressions? Can graphical means assist the humanities in the project of interpretation? Of self-conscious awareness about the act of knowing how we think as well as what we think about?

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[1] René Thom, "Stop Chance! Stop Noise!" in *SubStance* #40, 1982, p.9-21 special issue on OuLiPo early 1980s

[2] William Ivins, *Prints and Visual Communication* (Cambridge: Harvard University Press, 1952)

[3] The term "inter-subjectivty" comes from media theory, not Ivins's work. The work of John Dewey, taken up by James Carey, but also, the critical reconsideration of the role of readers and audiences, as well as social and historical theories of community formation founded on works by Emile Durkheim, Benedict Anderson, and others.

[4] Margery Senechal pointed out to me in conversation that given Thom's engagement with visual forms in his own work, the tone of disciplinary rigor in this situation might be accounted for by the context. After all, Thom had seen his own catastrophe theory used and mis-used across a wide range of popular and often highly distorting locales and he was focusing his attack on the OuLiPo community, with their ludic but irreverent imaginative sensibility. As a mathematician and historian of mathematics, Senechal suggests that Thom took visuality fully into account as an aspect of his own work and thought.

[5] Martin Jay, *Downcast Eyes: The denigration of vision in French Theory* (Berkeley: University of California Press, 1993).

[6] Thanks to Emily McVarish for comments on this passage, and for reminding me of the arguments within the visual arts and aesthetics in which the contrast of line and color establish their own hierarchy. This replicates some of the value judgments that align delineation and intellect and color and sensuality in a long-standing tradition. She referred me to the work of Jacqueline Lichtenstein, and opened the door to the host of other significant philosophical critics of visuality Jean-Claude Leibenstein, Louis Marin, Hubert Damisch, and Mieke Bal.

[7] Humberto Maturana and Francisco Varela, *The Tree of Knowledge*(Boston: Shambala, 1987) and *Autopoiesis and cognition : the realization of the living,* (Dordrecht, Holland ; Boston : D. Reidel Pub. Co., 1980),. also Heinz von Forrester. For an image, see Johann Stradanus, *Nova Reperta* and the plate showing America.

[8] See: www.speculativecomputing.org for work by SpecLab (co-founded by Jerome McGann and myself, at the University of Virginia, and my essay "Speculative COmputing" in the

forthcoming *Blackwell's Companion to Digital Humanities*, John Unsworth and Susan Schreibman, editors., (Oxford: Blackwell's Publishing, 2005)

[9] See Mark Hansen, *New Philosophy for New Media* (Cambridge and London: MIT Press, 2005) for a discussion of embodiment and the technology of vision.

[10] A consideration for economy of expression here condenses complex discussions of the constitution of a representational system and the relation between an image or sign of any kind and that which it supposedly "represents." The history of semiotic, structuralist, and post-structuralist literature abounds with discussions of the extent to which the assumed autonomy of the referent, it's a priori existence, self-sufficient status or any other claim to ontological existence can be understood. Jacques Derrida's *Of Grammatology* is perhaps the outstanding text, but works by Umberto Eco, Jonathan Culler, A.J. Greimas, Hubert Damisch, Jean-Francois Lyotard, Jean Baudrillard, Gaytri Spivak, Julia Kristeva, Norman Bryson, Terry Eagleton, Christian Metz, among a host of others constitute the core body of literature in this field.

[11] Need a reference for the "drawing across cultures" concept.

[12] Ernst Gombrich, *Art and Illusio*n, (New York: Bollingen, Pantheon, 1961), and of course, Norman Bryson's trenchant critical study of Gombrich, *Vision and Painting: the Logic of the Gaze* (Cambridge: Harvard University Press, 1983).

[13] James Jerome Gibson, *The ecological approach to visual perception*, (Hillsdale, N.J. : Lawrence Erlbaum Associates, 1986, originally published in 1979.)

[14] What the Frog's Eye Tells the Frog's Brain , Lettvin, J.Y., Maturana, H.R., McCulloch, W.S., & Pitts, W.H. (1959), *Proceedings of the IRE,* Vol. 47, No. 11, pp. 1940-51.., Stephen

Kosslyn,*Image and Mind* (Cambridge: Harvard University press, 1980), Richard L. Gregory, *Eye and Brain* (Princeton: Princeton University Press, 1990).

[15] *Picturing science, producing art,* Caroline A. Jones, Peter Galison, editors, with Amy Slaton.

(New York : Routledge, 1998).

[16] Peter Galison, *Image and Logic: A material culture of microphysics* (Chicago and London: University of Chicago Press, 1997)

[17] James Carey, "Cultural approach to Communication," Chapter 1, *Communication as Culture* (Boston: Unwin Hyman, 1989), p. 26, citing Eric Veoglin in a larger discussion taking off from John Dewey, Emile Durkheim, Max Weber, Perry Miller, Ernst Cassirer and other critical historians of symbolic form.

[18] The proceedings of the Science and Art Symposia, Leonardo magazine, works by Martin Kemp, *Visualizations: The nature book of art and science* (Berkeley: UC Press, 2000), Stephen Wilson, *Information Arts* (Cambridge: MIT, 2002), or David Freedberg, *Eye of the Lynx* (Chicago: University of Chicago Press, 2002), and the works by Galison and Jones op.cit.

[19] Martin Davis, *The Universal Computer* (NY: Norton, 2000)

[20] Martin Davis, op.cit.

[21] William Ivins, *Art and Geometry*, (NY: Dover Publications, 1946) makes the point that geometrical figures can be understood and manipulated tangibly as well, and that many geometric proofs are elaborations of physical actions such as turning, layering, or placing shapes in relation to each other.

[22] Eugene Ferguson, *Engineering and the Mind's Eye* (Cambridge: MIT Press, 1992

[23] *From Memex to hypertext : Vannevar Bush and the mind's machine*, James M. Nyce and Paul Kahn, editors. (Boston : Academic Press, c1991).

[25] Michael Leyton, Process Grammars, J.Gips and etc. for Shape Grammars. Shape grammar discussions date from the 1970s, process grammar is a more recent development for which Leyton takes major credit.

[26] Software programs for computer aided design of engineering and manufacturing link graphical forms and specific operations such as extrusion, cutting, properties of materials and surfaces, changing the basic drawing task into an industrially oriented instruction set for production.

[27] A familiar example would be the structure of a landscape presentation with foreground, middle ground, and background as conventions for organizing information in a relationship that is graphically coded. Proximity is semantic, not only syntactic, in such a structure and the use of different ways of working a surface tone to indicate degrees of distance is a graphical code that articulates the visual distinctions among different orders of knowledge in that field.

[28] Franco Moretti, "Graphs, Maps, and Trees," No, 24, November-December 2003, *New Left Review* first of three articles. http://www.newleftreview.net/Issue24.asp?Article=05 (11/12/04)

[29] See Text Visualization paper.

[30] Susan Hockey, *Electronic Texts in the H umanities,* (Oxford: Oxford University Press, 2000), for a pragmatic and reasoned approach; Jerome McGann, *Radiant Textuality* (New York: Palgrave, 2001) for a theoretical discussion, and the forthcoming Blackwell's

Companion to Digital Humanities for various perspectives, and the publications of the ACH/ALLC.

[31] The term "marked" is meant in a vernacular and technical sense that references "mark-up" or the use of tags in electronic text to serve description, analytic, and display functions.

[32] For a basic, well-grounded introduction to the basics see: *Designing the user interface : strategies for effective human-computer interaction,* Ben Shneiderman, Catherine Plaisant. (Boston : Pearson/Addison Wesley, c2005). Schneideriman is a rational empiricist without a whiff of post-structuralist or theoretical awareness, but an expert designer and skilled practitioner of the highest order.

[33] Software for the processing of textual material into visualizations, such as TextArc, GraphViz etc.

[34] See, Johanna Drucker, "The Virtual Codex: From Page Space to E-Space," www.philobiblon.com/drucker/, and the forthcoming "Graphical Readings" in TEXT.

[35] Keith Smith, *Structure of the Visual Book*, (Rochester: Keith Smith Books, 1984 and subsequent editions)

[36] "The Virtual Codex", op.cit.

[37] Michael Holly, Keith Moxey, Mieke Bal, or Laurie Adams, The methodologies of art, (NY: Icon, 1996)

[38] Obviously this is a distorted statement. The examination of epistemes is integral to the practice of art history. The distinction I am trying to draw is important, however, since the art historical undertstnding doesn't have as its goal the description of graphical knowledge forms, but other histories and concerns.

[39] For example, *Beauty of another order : photography in science*, Ann Thomas ; with essays by Marta Braun ... [et al. (New Haven, CT : Yale University Press in association with the National Gallery of Canada, Ottawa , 1997)

[40] James Elkins, *The Domain of Images* (London and Ithaca: Cornell University Press, 1999)

[41] *Eye of the Lynx*, nature illustration history, history of botanical and zoological illustration etc.

[42] William Ivins, *The Rationalization of Sight* is a good place to begin that literature, but John White, Miriam Bunim, Hubert Damisch, Erwin Panofsky, and Victor Burgin are all useful, as is Norman Bryson.

[43] Estelle Jussim, Visual communication and the graphic arts; photographic technologies in the nineteenth century. (New York, R. R. Bowker Co., 1974).

[44] Ivins, *Prints and Visual Communication*, op.cit.

[45] Franco Moretti, 'Graphs, Bars, and Diagrams" op.cit. in a passing comment at the beginning of his article inspired this elaborated discussion.

[46] I'm gesturing towards the longer history and broader usage of these forms. Print culture stabilizes and reproduces these forms, and the tabular forms are particularly suited to letterpress print technology and share its ideological impact.

[47] http://www-gap.dcs.st-and.ac.uk/~history/HistTopics/Topology_in_mathematics.html (11.12.04)

[48] I'm thinking of film editing and other analyses of time-based media.

[49] Martin Campbell-Kelly and William Aspray, *Computer: a history of the machine* (Boulder: Westview Press, 2004 and earlier editions)

[50] Daniel Crevier, *AI : the tumultuous history of the search for artificial intelligence* (NY : Basic Books, 1993). is a good basic introduction to this concept and its intellectual development.

[51] Michael de Certeau, *Heterologies,(*(Manchester: Manchester University Press, 1986), translated by Wlad Godzich, Michael Foucault, *The Order of Things* (NY: Pantheon, 1970), Jean-Francois Lyotard,*The Postmodern Condition* (Manchester: Manchester University Press, 1984) and Jaen Baudrillard, *For a Critique of the Political Economy of the Sign,* (St Louis, MO: Telos Press, 1981).

[52] Richard Saul Wurman, *Information Design*

[53] Edward Tufte, *The Visual Display of Quantitative Information*, "Graphical Excellence," p. 13. (Cheshire, Connecticut: Graphics Press, 2001). Tuftte's work is extremely important in many ways. The aesthetic, critical, and historical dimensions of his contribution are substantive. But the basic premise of this work resides on a theoretical orthodoxy I find suspect. And Edward Tufte, *Envisioning Information* (Chesire CT: Graphics Press, 1990)

[54] Earlier instances, Owen Jones, *The Grammar of Ornament*, but also, architectural treatises, the classical orders, Palladio, Vitruvius, etc. through the Renaissance. But graphic arts didn't adopt a self-consciously systematic approach until the 20th century.

[55] Wassily Kandkinsky, *Point and Line to Plane* (NY: Dover, 1979, unabridged republication of the 1947 publication of the Museum of Non-Objective Painting) p.145. See also Patricia Railing, *From Science to Systems of Art: On Russian Abstract Art and Language 1910/1920 and other essays* (East Sussex: Artists Bookworks, 1989).

[56] Charles Peirce, *The Philosophical Writings of Charles Peirce*, edited by Justus Buchler (NY: Dover, 1955, republication of the 1940 edition of "The Philosophy of Peirce: Selected Writings," Routledge and Kegan Paul, Ltd., London)

[57] Ladislav Matejka andIrwin R. Titunik, eds., *Semiotics of Art* (Cambridge, MA: MIT Press, 1976).

[58] Roland Barthes, *Elements of Semiology* (NY: Hill and Wang, 1968), *Image/Music/Text* (NY: Hill and Wang, 1977).

[59] Jacques Bertin , *The Semiology of Graphics* (Madison: University of Wisconsin Press, 1973) and Fernande Saint-Martin, *Semiotics of Visual Language* (Bloomington: University of Indiana Press, 1990)

[60] David Marr, *Vision:* a computational investigation into the human representation and processing of visual information (SF; W.H. Freeman, 1982).

[61] Max Wertheimer , *Productive thinking*, edited by Michael Wertheimer. (Westport, Conn. : Greenwood Press, 1978, 1959).

[62] Alan MacEachren, *How Maps Work* (NY and London: Guilford Press, 1995)

[63] Paul Mijksenaar, *Visual Function* (Princeton: Princeton Architectural Press, 1987)

[64] See Pamela McCorduck, *Machines Who Think*, (SF: W.H. Freeman, 1979), Daniel Crevier, *The AI Debates*, and an enormous body of literature including work by Norbert Wiener, Esther Dyson, Freeman Dyson, Howard Rheingold, and many others.

[65] Humberto Maturana and Francisco Varela, *The Tree of Knowledge*(Boston: Shambala, 1987) and *Autopoiesis and cognition : the realization of the living,* (Dordrecht, Holland ; Boston : D. Reidel Pub. Co., 1980), also Ernst von Glasersfeld, *Radical Constructivism* (London and Washington, DC: Falmer Press, 1995).

[66] McGann , *Radiant textuality*, op.cit.

[67] Michael Guichard, "The Precursors of the Written Word in the Danube River Basin," *A History of Writing*, Ann-Marie Christin, ed., (Paris: Flammarion, 2001), pp.17-19.

[68] Ernst Fraenkel, *Les Dessins Trans-Conscients de Stephane Mallarmé* (Paris: Librarie Nizet, 1960)

[69] See www.speculativecomputing.org for an archive of the Temporal Modelling project.