The Semiotics of the Digital Image

Patricia Search
Rensselaer Polytechnic Institute
Troy, New York 12180 USA

Contemporary art criticism is deeply rooted in modernist and postmodernist theories. Modernism, which drew on the formalist theories of critics like Ad Reinhardt and Clement Greenberg, was a period of art-for-art's sake that called for "pure painting" that was free of "illustration, distortion, illusion, allusion or delusion" [1]. For Clement Greenberg, the physical dimensions of the medium defined "pure painting" and "pure sculpture." Artists stripped their paintings of three-dimensional illusions and embarked on academic studies that emphasized "the flat surface, the [rectangular] shape of the support, the properties of pigment" [2]. Greenberg's formalist theories sought to establish objective criteria for the evaluation of art based on this interaction of form and medium. Modernist theory, however, was highly deterministic with only one approach to evaluating the aesthetic quality of artwork.

As formalism reached a peak in the 1960s, body, performance, pop, and conceptual art rejected the modernist doctrine and ushered in the era of postmodernism which challenged all restrictions on form and aesthetics. For many theorists, the fragmented pluralism of postmodernism led to ". . . depthless styles, refusing, eluding, interpretation" [3].

Out of this aesthetic chaos, new forms of artwork emerged including artworks that use computer graphics as an integral part of the design process. However, much of this art is criticized for its lack of aesthetic quality, with critics maintaining that the work merely imitates earlier art forms. In many instances, the critical theories of modernist and postmodernist discourse define these evaluative criteria. Reminiscent of the modernist doctrine, many writings highlight characteristics of the digital medium such as kinetics, interaction and networking, simulation, virtual reality, and numerical analysis as the principle criteria for defining and evaluating the aesthetics of digital art. Critics often misinterpret works that do not exhibit these attributes as artwork that could have been done in another medium without the use of electronic technology.

This approach to evaluating digital art overlooks the semiotics of the digital image in which symbols become interpretations of symbols, and multiple levels of graphic encoding take on discursive characteristics similar to linguistic syntax. As this conceptual environment of symbols and text replaces tactile and kinesthetic interaction with the artwork, new forms of creative expression codify form, space, action, and time into diverse levels of abstraction. Unlike the fragmented visions of the postmodernist period, these works merge discrete concepts into fluid, integrated statements.

This paper examines the semiotics of the digital image within the context of philosophical developments in mathematics and physics. In these fields, causality and deterministic logic have been replaced by "descriptive" mathematics and scientific theories of relativity and quantum mechanics. The concepts behind these new scientific models of reality are also an integral part of the semantic-syntactic structure of the digital image.

The Visual Logic of Descriptive Geometry

Geometry is one of the oldest branches of mathematics and the architectural framework for computer graphics. The term *geometry* is derived from the Greek words meaning "earth measurement," and early Euclidean geometry used deductive methods to study flat surfaces (plane geometry) and rigid three-dimensional objects (solid geometry). These linear, static methodologies were based on sets of unproven assumptions called axioms that were derived from perception and experience.

Mathematicians gradually realized that these intuitive assumptions should be replaced by abstract terms devoid of preconceived meaning. This type of formal system would provide a more flexible structure for evaluating spatial relationships. In 1637, Descartes used algebraic equations to visualize points, lines, and forms, thus raising the study of geometry to a new level of abstraction by detaching it from its perceptual base. However, Cartesian geometry, like Euclidean geometry, was still founded on deterministic logic and deductive reasoning.

The 1800s brought new philosophical and scientific inquiries into the relationship between optical truth and interpretation. Mathematicians reevaluated traditional assumptions about space. New theories evolved that further underscored the need for geometric systems that were not based on the intuitive perception of space and time. In 1854, for example, a German mathematician named Georg Riemann postulated that space could be curved--a theory that Einstein later used to develop relativity. Riemann's research, along with the work of other mathematicians in the nineteenth century, required new methods of defining and visualizing spatiotemporal concepts. The linear determinism of Euclidean geometry was slowly replaced by mathematical models that described multidimensional abstract relationships. The dynamic interaction of these spatiotemporal descriptions was reflected in new mathematical terms such as *betweenness*, *projective*, *translation*, *reflection*, *hyperplanar*, and *inversive*.

In the 1960s, with the help of computer graphics, mathematicians bridged the gap between symbolic descriptions and perception by using patterns to visualize logical processes and simultaneous relationships. Mathematician Lynn Steen describes mathematics as a "science of patterns" with abstract levels of visual encoding in which "theories emerge as patterns of patterns" [4]. In this new descriptive geometry, perceptual references symbolize dynamic processes and interrelationships that change over time. Logical analysis is augmented by the perceptual, holistic synthesis of visual patterns. According to mathematician Jacques Hadamard, images are important to provide a "simultaneous view of all the arguments" [5].

The *visual logic* of descriptive geometry enables mathematicians to understand the structure of a problem and then reconstruct and improve their intuitive understanding of numerical relationships. Multiple levels of perceptual encoding create a model for describing "those aspects of visual modes of thought that appear to lie beyond the analogy of mere sight" [6]. Mathematicians can analyze the syntactical components of geometric space and then synthesize those relationships into an integrated system.

Metastructural Models in Physics

Like early Euclidean geometry, classical physics was built on deterministic logic and reductionist theories that limited the interpretation of physical forces to strict causation. Newtonian mechanics, for instance, was built on the reductionist theory that time and space were rigid and constant. Newton described time and space as follows:

> Absolute, True, and Mathematical Time . . . flows equably without regard to any thing external. . . . Absolute Space, in its own nature, without regard to any thing external, remains always similar and immovable [7].

In classical physics, reality was an objective truth, and the scientist was a passive observer looking on. However, in science like mathematics, theories of indeterminism eventually replaced Aristotelian logic. With the introduction of relativity and quantum physics, a new scientific model of the world emerged in which dynamic interactions replaced static, linear forces.

In his theory of relativity, Einstein demonstrated that space and time are not absolute. Both space and time are multidimensional forces that defy the limitations of perceptual interpretation. At lightspeed, for example, time encompasses both the present and the future. In effect, time ceases to change because it contains all change [8]. Spatial representations also merge at high speeds. As space is compressed, multiple views of objects are possible from a single perspective because planes and volumes become one [9].

Quantum physics continued to develop this pluralistic and highly abstract model of spatiotemporal interaction. Traditional observations about the physical world broke down in the microscopic world of quantum mechanics. Scientists needed new theories to explain the indeterministic and highly interactive nature of subatomic units. In 1926 Niels Bohr developed the theory of complementarity to describe the antithetical duality of physical forces [10]. Light, for instance, is *both* a wave *and* a particle. However, light reveals only one attribute at a time, and the scientist determines that attribute by the type of measuring device used in an experiment. Scientists also learned that multiple forces such as gravitation, nuclear forces, and electromagnetism can operate simultaneously in the same place [11]. In this multidimensional model, physicists discovered the "quantum leap," the fact that electrons can move between orbits and simultaneously appear in another orbit without traversing the intervening space [12]. The linear dimensions of strict causation that characterized classical physics were replaced by a matrix of interactive relationships.

The world of quantum physics raised as many questions as answers. There was no longer any such thing as "objective" reality. Relationships were defined by the participation and interpretation of the observer. Like the mathematicians of the time, scientists learned that they could no longer rely on intuition and experience to define physical forces. They needed to build a flexible, abstract framework for a virtual world with tentative truths.

The Semiotics of the Digital Image

Mathematicians and physicists demonstrated that we cannot rely on our perceptual interpretations of reality. Instead, we must raise our intuitive knowledge of space and time to a higher level of abstraction that defines the dynamics between perception and reality. Once we identify these interactive forces, we can create multidimensional models that integrate mathematical laws and interpretation into virtual extensions of the physical world.

Psychologists call this process of redefining perceptual knowledge "reflective abstraction." Computers have made it easier for mathematicians, scientists, and artists to use this process to visualize and construct new knowledge beyond the boundaries of logic and expectation. In art, the results are a new visual aesthetic that echoes the philosophical perspectives of modern mathematics and physics in the following dimensions of digital semiotics:

- Metastructural Dynamics
- Cognitive Mapping
- Visual Logic

This paper discusses each of these points and cites examples of representative artwork. Due to space restrictions, it was not possible to include illustrations of the many works of art that are mentioned. However, the reference list at the end of the paper includes sources for the cited works [13].

Metastructural Dynamics

In computer graphics, terms like *three-dimensional model*, *rendering*, and *simulation* suggest an artificial retreat from reality. However, artists are actually using these techniques to visualize scientific interpretations of reality by creating metastructural environments that expand the intuitive dimensions of space and time into abstract models of a dynamic, virtual world.

Using an architectonic system of mathematically defined forms, colors, compositions, and perspectives, an artist can control the hierarchy of geometric relationships and redefine the geometric syntax of experiential space and time. The use of geometric coordinates to specify spatial relationships has shifted the artistic focus to linear and surface projections rather than perspective projections. Working with subtle changes in the attributes of lines such as width, color, texture, and position, artists transform the planar dimensions of linearity into volumetric extensions of space. This type of "linear space" is an integral part of works by artists such as Eudice Feder (*Separation*, 1980; *Permutations*, 1980; *Wind-Warn*, 1985), Herbert Franke (*Serie 1956*, 1956; *Grafik I*, 1956), and A. Michael Noll (*Ninety computer-generated sinusoids with linearly increasing period*, 1965). These artists use precise, geometrically controlled lines to create multiple levels of perceptual space. Tony Longson adds a physical dimension to this concept of linear space by creating line and "tonal" drawings on multiple panels of Plexiglas and then overlapping the panels to create three-dimensional constructions (*Group Theory Grid*, 1968; *Square Tonal Drawing #2*, 1980).

For other artists, surface rather than linear projections shape the metastructural dynamics of space and time. In works by Manuel Barbadillo (*Untitled*, 1975) and Vera Molnar (*Hypertransformations*, 1973-6), geometric progressions define randomly shaped, interlocking planes of color with ubiquitous perspectives and spatial orientations. In these works, the two-dimensional space becomes all-inclusive and folds into itself much like the curved space of modern geometry and physics.

The medium of light in computer graphics also transforms the spatial dimensions of lines and planes. For example, in works by Ben Laposky (*Oscillon 40*, 1952; *Oscillon*, 1956) and Kathleen Dolberg (*Gossamer*, 1984), transparent filaments of light create flowing shapes that engulf the surrounding space and blur the perceptual boundaries between lines, surfaces, three-dimensional space, and infinity. The medium of light also defines different levels of linear and surface space in the "virtual sculptures" of Michael O'Rourke. These two-dimensional images juxtapose definitive geometric lines and objects with diffuse areas of modulated colors. This visual interplay between light and space is sensually articulated in O'Rourke's backlit transparencies such as *Manhattan Invitation* (1988).

The reflective and refractive qualities of light also enable artists to visualize the spatial relationships *in* and *between* objects. In the animations of Yoichiro Kawaguchi (*Origin*, 1985; *Ocean*, 1988), reflective and transparent surfaces transform the organic forms into mirrored visions of space within space. The images embrace space and time from all directions rather than limiting the vantage point to a unique perspective. Like the works of Barbadillo and Molnar, space becomes all-inclusive and nonlinear.

Time, in particular the spatial representation of time, establishes a conceptual link between the physical and virtual dimensions of these metastructural models. Time is defined as an infinite extension of space and form through the mathematical abstraction of lines, angles, and curves. The geometric syntax of the fractal image is an excellent example of this temporal link between the physical and virtual dimensions of reality. In other artwork, such as Kawaguchi's art, time is defined by reflective and transparent objects that visualize the passage of light through space. In these images, layers of visual data define multidimensional arrays that visualize simultaneous and sequential levels of spatiotemporal perception.

The metastructural dynamics of the digital image integrates structure and control into a spatiotemporal continuum that defines an infinite, virtual space. This visual dichotomy is especially evident in artwork that juxtaposes the definitive geometry of three-dimensional objects with subtle gradations of texture, color, transparency, or reflection. The computer paintings of David Em (*Redbal*, 1980; *Zotz*, 1985) and my own artwork (*Rhapsody in Time*, 1986; *Coloratura 100*, 1988; *Kaleidoscope*, 1992) represent this type of visual model (see Figure 1). In these images, geometric objects anchor the work in the logical dimensions of space and time while perceptual transformations challenge the limitations of experiential reality.

Cognitive Mapping

The mathematical models of descriptive geometry, relativity, and quantum mechanics emphasized interactive webs of sequential and simultaneous events. In many forms of digital art,

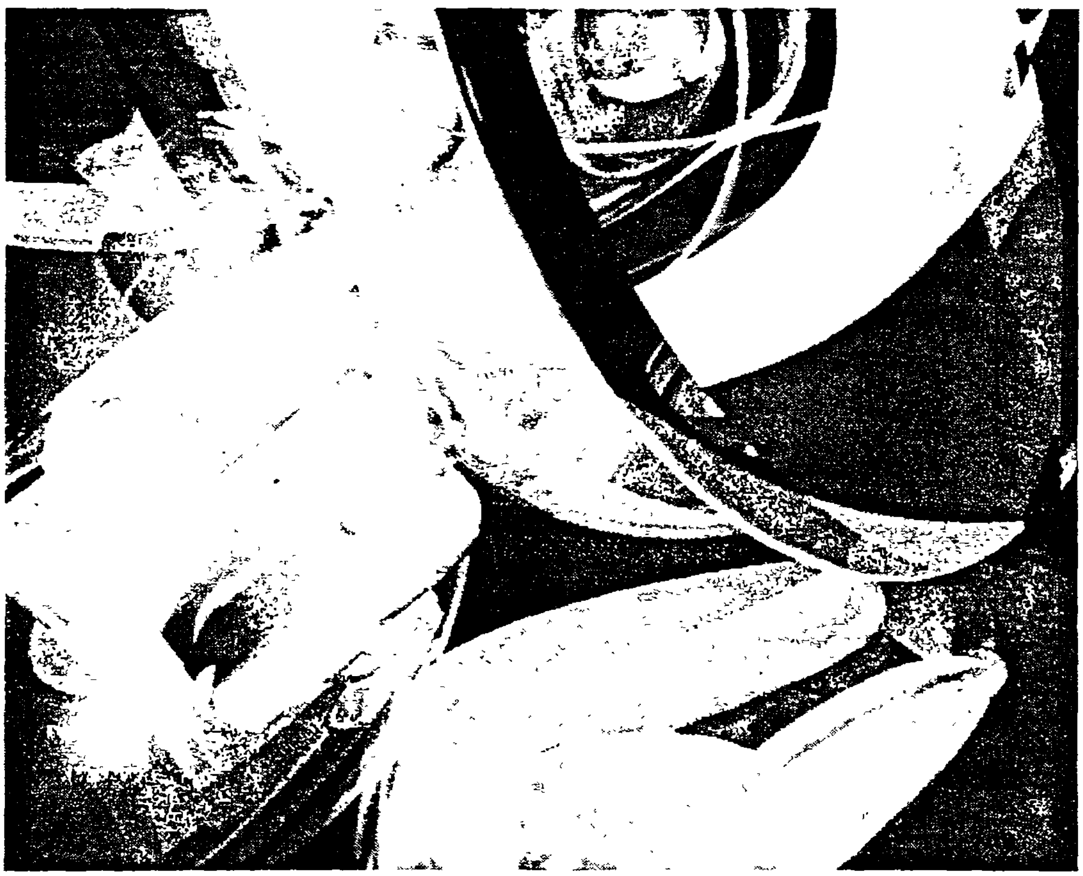

Figure 1. *Kaleidoscope* by Patricia Search integrates geometric structure and control into an abstract, virtual space. (Copyright 1992 by Patricia Search. All rights reserved.)

perceptual and cognitive processes define a matrix of temporal relationships, resulting in a complex network of associations.

In some artwork, this multidimensional structure visualizes the geometric syntax of space and time. Bruce and Susan Hamilton, for example, use computer graphics to create conceptual drawings for sculptures like *Tetrad* (1984), *Metamorphosis III* (1987), and *Scarab* (1990). In these works, mathematically defined proportions create a geometric balance between lines, planes, textures, and color. The mathematical syntax of these sculptures not only visualizes logical, sequential processes but also provides a syntactic filter for simultaneously mapping multiple perspectives in space and time.

Other artists use a dynamic, visual-linguistic syntax to construct interactive webs of associations. In *Random Ranson* (1986) and *Indicted Invited* (1988), Tom Leeser extracts images and text from their original sources and integrates them into a "media archeology" that challenges their original meanings and context [14]. Paul Berger creates digital photographs that visualize the cognitive networks of information in a database. In works like *Print-Out* (1988), Berger uses photocopied lists of database entries as backgrounds for photographic portraits [15].

In interactive works of art, narrative intention increases the complexity of cognitive mapping. The viewer expects to construct meaningful relationships and must continually redefine the webs of interaction between expectations and reality. Abbe Don explores these issues in *We Make Memories*, an interactive program that allows viewers to create stories by experimenting with the associative links between content, structure, and context [16].

In the digital image, a semantic-syntactic network of images, text, and sound directs actions and expectations. The viewer constructs a system of relational codes that becomes an integral part of the interpretation of the work. Multiple levels of perception and cognition may exist within individual symbols. Jim Johnson, for instance, creates bookworks with symbols that integrate visual and linguistic semiotics. Using computer graphics, Johnson has designed a "Skeletons" font that is derived from silhouette drawings of skeletons. In the book *Dead Air* (1991), he uses this font to form words that complete phrases beginning with the word "dead," phrases such as *dead wrong* and *dead last* [17].

The work of artist Jim Rosenberg adds another level of inquiry to these visual-linguistic maps. He uses "word clusters" to experiment with the syntax of words that occupy the same point in logical and physical space. In his interactive program *Intergrams* (1990), a group of phrases is indecipherable when the phrases overlap each other in the same space. However, moving the computer mouse over the cluster discloses individual phrases and hides the remaining ones, revealing the meaning of the cluster [18].

The use of symbols to map perceptual and cognitive associations is an important dimension in the semiotics of the digital image. Like the recursive patterns in mathematics, symbols become interpretations of symbols. Thorne Shipley conducts theoretical research in "pattern and matrix vision" [19]. His work investigates the different levels of perception and cognition that are defined by visual patterns or textures in linguistic messages. Unlike Johnson who maps synonymic associations between words and images, Shipley is exploring what he terms "heterological message duality" or "message multiplicity" [20]. He illustrates this concept using words that are typographically constructed from other words. For example, in one of his illustrations, the text for the word *yes* is repeated in a pattern that forms the shapes of the letters in the word *no*. Similarly, the text for the word *you* forms the shape of an *I*, and the word *will* creates each of the letters in the word *won't*. When these typographical constructions appear in phrases like *No, I won't*, the visual patterns within each word communicate a secondary message--*Yes, you will* [21].

Future research and investigation will expand the semantic-syntactic dynamics of these types of cognitive maps. As artists expand their use of interactive multimedia in artwork, they will find new ways to add levels of sensory interaction to the layers of relational encoding. Artists will also learn how to integrate the linguistic patterns of user interfaces and programming languages into these visual symbols, adding still another interpretive link to the semiotic structure of these cognitive maps.

Visual Logic

Just as writing fostered the development of abstract thinking with the implementation of symbols and sounds to designate thoughts, the mathematical syntax of computer graphics defines another level of abstract thinking called visual logic. However, unlike writing that separated data from interpretation, this new abstract symbolism uses visual perception to synthesize data and interpretation into an integrated whole.

Artists, like mathematicians and scientists, use visual patterns to improve their intuitive understanding of logical and perceptual relationships. Many artists, for example, use computer graphics to investigate the logical and intuitive dimensions of design. The grid, which postmodernists rejected as a symbol of structural control, has resurfaced as an intuitive symbol of the underlying structure of spatiotemporal procedures. Daniela Bertol's collage *Bending and Twisting: Hypothesis #3* (1988) uses a twisted geometric grid to visualize the algorithmic structure of space and time. The grid is also an integral part of Andrew Glassner's *Celtic Knot* series (1987), black and white drawings that investigate the geometry and form of Celtic knot weaving. In these works, Glassner uses an invisible grid to create a visual pattern that symbolizes the spatiotemporal relationships in the perception and comprehension of this intricate weaving procedure.

Some artists use design techniques to create a multidimensional syntax that articulates the interaction of perception and cognition. For over twenty years, Manfred Mohr has been using computer graphics to analyze the relationships of lines in the cube (*P-26/2 Inversion Logique*, 1969; *P-155 Cubic Limit*, 1974-6; *P-306 Divisibility I*, 1980-3; *P-370-P Divisibility II*, 1985). Mohr uses the twelve lines that make up a cube to create a new visual language that "disrupts the symmetry of the cube" [22]. In his prints, individual lines, which form discrete units of information, create a visual syntax that signifies the sequential steps in the perception of geometric forms and space. At the same time, his designs form an integrated whole in which black and gray lines establish contrasting layers of perceptual events that disrupt the sequentiality and order of the mathematical logic.

Artists also use the visual logic of computer graphics to explore the intuitive synthesis of logical events. By juxtaposing text and images that symbolize procedures or actions with images that represent the end results of those actions, the artist constructs an interpretive dialogue that visualizes the temporal transformation of ideas. Colette and Charles Bangert, for example, use computer graphics to investigate how mathematical models visualize various types of forms (*Large Landscape: Ochre & Black*, 1970; *Circe's Window*, 1985; *Katie Series*, 1986-7). The software they have developed explores the relationships between numerical functions and the drawing process:

> At the time the programs were written, we thought of the transforms and the interactions of the instances. Now we think of the whole drawing as a picture of a single line in a high dimensional space [23].

Margot Lovejoy uses mathematical symbols to visualize the perceptual and logical representation of spatiotemporal relationships. In two-dimensional works such as *Azimuth I*

(1983) and *Azimuth II* (1983), geometric shapes, angled lines, geographical maps, and architectural drawings create a visual syntax that signifies the perceptual and cognitive processes involved in the interpretation of two-dimensional representations of space. Lovejoy's three-dimensional installations integrate physical space and time into the visual logic of spatiotemporal perception. In *Azimuth XX -- The Logic Stage* (1988), the artist juxtaposes three-dimensional, geometric forms with linear perspective grids that are projected onto the surrounding walls. Lovejoy describes her work as "the struggle to control, represent, and construct meaning in the 'gap between art and life' " [24].

The visual logic of the digital image is highly modular. Visual symbols can be rearranged to create new syntactical relationships. Digital images assume many characteristics of linguistic syntax but without jeopardizing their perceptual immediacy. The high level of abstraction in this visual system transcends the constraints of verbal language. The visual logic of the digital image shares many of the conceptual attributes of "metaphorms," visual metaphors that Todd Siler creates to describe the temporal and procedural relationships between art and science. Siler describes the power of metaphorms as follows:

> In metaphorming something, we can traverse the constraints of logic and verbal thought, transferring or relating from one object to another a new meaning, pattern, or set of associations. Like the language of pure mathematics, which can describe abstract *n*th-dimensional processes and forms, the symbolic language of metaphorms is also multidimensional. It operates simultaneously on many planes of associations, nuances, and meanings [25].

Conclusion

Modern mathematics and physics demonstrated that we need to develop abstract models of reality that are flexible enough to accommodate the shifting dynamics of a wide range of variables, including the subjective decisions and interpretations of the observer. To understand these multiple levels of interaction, these models must acknowledge differences as well as interactive relationships. Only then can we build a model that is flexible enough to change with new perspectives and observations. As Marvin Minksy points out in *The Society of Mind*,

> We usually like to think in positive terms about how various parts of systems interact. But to do that, we must first have good ideas about which aspects of a system do *not* interact. . . . In other words, we have to understand *insulations* before we can comprehend interactions [26].

For mathematicians, scientists, and artists, computer graphics provides a powerful tool for visualizing the insulations *and* interactions of a multidimensional system. The digital image integrates the structural control of analytical processes with the holistic powers of perception and interpretation. Artworks abandon the predictable, deterministic logic of the modernist period and the eccentric, fragmented pluralism of postmodernism which was characterized by random, irrational infrastructures. In the digital image, the geometry of mathematics and the logical syntax of programming languages create a conceptual framework for synthesizing complex webs of interactions.

In the future, new technology will alter the semiotics of the digital image. High-definition television, for example, will modify established perceptions in space and time. High-resolution displays will place an added emphasis on detail and text and increase the prominence of background imagery. As digital displays acquire the scale of actual walls, the syntactic structure of the image will become an integral part of the surrounding architectural space. In addition, the electronic dissemination of art, coupled with interactivity and collaborative networking, will increase the temporal dynamics of the digital image.

All of these developments further mandate the need for a new design discourse, perhaps based on an interactive audiovisual language, that reflects the dynamic structure of the digital image. Artists, mathematicians, and scientists are no longer concerned with a single view or interpretation of reality. Instead, the emphasis is on using digital technology to modify perceptions and restructure information. Models of reality, defined by abstract descriptions of tentative truths, are subject to constant reevaluation. This dialogue between logic and perception leads to an eternal quest for new perspectives--a quest that Minsky describes as the interaction of two types of complementary knowledge:

> We search for "islands of consistency" within which ordinary reasoning seems safe. We work also to find and mark the unsafe boundaries of those domains [27].

The semiotic structure of the digital image visualizes these complementary forces and helps us understand the limitations of perception and reason, thus enabling us to transform those "unsafe" boundaries into new knowledge and insights about the complex world around us.

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