Visual Semiosis Applied to Computer Graphics

While there is almost a consensus that the visual plays a very important role in design, communication, and memory, little has been done to clarify why and how this happens. In other words, the practice of the visual in its various forms is far more advanced than the theory and methodology of the visual. There is nothing unusual in this situation, except that the visual is not a recent acquisition or discovery. Quite to the contrary. It precedes the word and articulated language. It has a long history of being used and explained. But there is still no comprehensive theory or consistent method or methods, that can be applied whenever people design, communicate, or memorize something. Recent developments in computation, especially what is called *symbolic computation,* identified the visual as crucial to our attempts to better understand human intelligence. To no one's surprise, vision has become a constitutive part of artificial intelligence, which in its turn acknowledges the importance of the field of the visual despite the lack of theory and methods for improving our visual performance.

In the framework of these developments, marked by some interesting contributions from cognitive scientists (Anderson, Marr, Spoehr, Lehmkuhle, among others), progress has been made towards better processing of visual information and towards algorithms for perspective representation, models of transparency, ray tracing, texture mapping, etc. Consequently, vision programs were written and computer graphics workstations became available. We can visualize, sometimes at high expense (in CPU cycles used or in memory needed or expressed in a not entirely justifiable cost/performance ratio), complex data appropriate to engineering applications and advanced research processing in physics, astronomy, and chemistry. We can better use images (scanned and digitized, various X-rays, holograms, etc.) and we dispose of new methods and means to generate visual representations (laser, magnetic resonance, texture mapping, etc.).

A tradition impossible to ignore is that of representing visual regularities in some mathematical formulation. The simplicity of the representation has, more often than not, made people believe that the visual must also be simple. The mathematics of the golden section, or the Fibonacci series, provides an example. Moreover, relations between the nature of the visual and biological, physical, and even underlying social structure have been considered, especially when issues of recognition were raised. A principle of syncretism between visual representations and biological, physical, or social phenomena was stated quite early in the history of our civilization. Indeed, simple rules are more general, and chances are that rules of the visual (like those referring to contrasts, continuity, depth, etc.) are cultural rules, i.e., acquired in the process through which humans use visual forms of representation for such purposes as design, communication, memory or art expression. Other rules (concerning symmetry, perspective, dynamics, etc.) are definitely cultural, i.e., based on shared notions. It should come as no surprise that modern art integrates many scientific observations regarding the visual (especially color theory, perspective, isomorphy, etc.) since it discovered things not exactly within the considered scope of art.

The visual is not only the manipulation of some underlying structures but a step towards structuring something similar to a language. This is a methodological innovation, affecting not only the use of the visual, but also its relations to the verbal, as well as to other forms of representation, communication, and expression. Computer-supported forms of representation are obviously influenced by the artistic approach mentioned before.

Contrary to dominant opinion, the computer is not primarily a number crunching machine, but a representation device, one of the most powerful and complex ever used. In order to represent, it has to crunch numbers--not the other way around. In other words, computer graphics is a powerful and unprecedented means of visually representing information. As such, it refers to a particular domain of the visual and requires a theory and a method of visual representation. Some will even say that it implies a visual language (if such a language can be defined and described).

At this point it is necessary to understand that after a rather long domination of verbal (sometimes called "natural") language, most people tend to explain everything in relation to this language. They go so far as to maintain the existence of a visual language and the possibility of describing it through some grammar applied to "primitive" visual components, i.e., a repertory. As a first step, they use already given grammars (the most successful application being Chomskyan generative grammars). Sometimes they even produce acceptable descriptions of complex visual images--*graftals* are a very good example). I do not intend to produce here the body of arguments proving the futility of this approach. Rather, my goal is to introduce a general theory and method--semiotics—as a potential candidate for making a methodology and theory of the visual possible and for applying it to computer graphics.

Semiotics is the general theory and practice of signs. It deals with everything that can be interpreted as a sign and defines the circumstances under which interpreting something as a sign allows for its better understanding, or for an improved use of it. The foundation of semiotics is logical. Charles Sanders Peirce, its modern proponent, conceived of semiotics as a new form of logic, adequate to the conditions of thinking, working, and creating characteristic of the age of science and technology. The encompassing pragmatic maxim resulting from the semiotic approach--an aspect quite often ignored—speaks about maximizing the effects of human activity. The maximizing of human activity (practical or theoretical) is the result of semiotic competence, i.e., of properly using and interpreting signs. So-called natural language, in which we speak and write, is but one example of a sign system culturally acknowledged, socially ratified, and used in politics, economics, and education.

The visual is obviously different from natural spoken language. But it can be identified semiotically either through some of its implicit properties or through the functions accomplished. Other examples of sign systems are: texture, the performing and plastic arts, literature, the system of sounds, notation (musical, mathematical, chemical). Despite the fact that a writer uses words from the language, the function of those words, as well as the function of more complicated structures, is quite different from business use of language from diplomatic, political, religious, and educational use. It is also very different from the use of language in computer programs, manuals for program users, and annotations to a program. There are instances when we want words to be used very precisely. There are others when the ambiguity of words, sentences, or texts is the main goal. The semiotics of the precise use of words is quite different from the semiotics of the ambiguous use of the same.

In the case of images, we face, from the very beginning, a different situation. Images are less determined in view of their use and interpretation. Context dependencies are quite different in the realm of the visual. There are more elements participating in the constitution of an image than in the reality of a sentence or a text. Even the "reading" of a written text is different from the reading of an image. We already know that sequences are different from configurations, that sequentiality and the digital are compatible, but that configurations are perhaps closer to analogous modes. All these distinctions and others should be kept in mind whenever we introduce such a general concept as the sign in order to avoid the reductionist approach typical of those convinced that a good linguistic theory will eventually explain the visual. The object of semiotics is sign systems and their functioning within culture.

To design means to put signs in relation and to convey, as clearly as possible, information about what is represented, the chosen mode of representation, and the goal of representation. Design principles are directly influenced by the way people structure representations conceived to facilitate the achievement of human goals. It deals with everything that can be: communication (as a form of social interaction), engineering (as a form of applied technical rationality), business (as a form of shared efficiency), architecture, education, etc. Along this line of thinking, Herbert Simon [1] stated, "Engineering, medicine, business, architecture, and painting are concerned not with how things are but with how things might be--in short, with design. Computer graphics is a particular form of design. To generate computer graphics, we use algorithms for various tasks and apply various means of image manipulation. These are all sign systems characterized by rules such as consistency, appropriateness, expressiveness, precision, economy, and quality. In our society, computer graphics functions at different levels: entertainment, visual communication, and engineering, to name a few.

In order to apply semiotics to computation, we need effective procedures and ways through which we can make such procedures computable. It is not sufficient to say that the object of semiotics is the sign and its functioning in different contexts. Without a definition that can be used in algorithms, we are bound to remain at the speculative level. Known definitions of the sign fall into two basic categories:

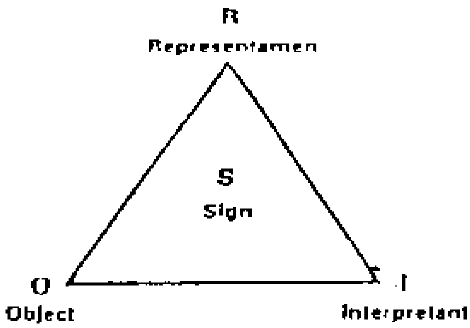
1) A particular type of sign is adopted as a paradigm and every other sign is considered structurally equivalent. For some reason, artificial intelligence researchers accepted this definition, which

originated in the works of the Swiss linguist Ferdinand de Saussure. At the beginning of the century, he advanced the paradigm of the sign as the unity between a *signifier* (the actual sign embodied in a certain material) and the *signified* (what the sign is supposed to mean).

2) A particular logical structure is adopted as the underlying principle of every sign interpretation. Charles Sanders Peirce (1839-1914, an American scientist, logician, and a pioneer in computers) advanced the definition of the sign as "something that stands to someone for something in some respect or capacity." Simon, dealing with the laws that govern strings of signs, mentioned the "air of contingency" signs have (as opposed to natural phenomena, which have an "air of necessity"). This panlogical definition of the sign is more appropriate to the subject approached here, first of all because the underlying principles of computers are themselves logical.

The sign definition can be formalized as follows: S=S(O, R, I, 0, i) in which
S represents the relation between the object represented (0), the representamen (R), and the interpretant (I), while o and i are operations from the representamen to the object, in particular, from the interpretation to the objects associated with the sign.

This definition is equivalent to the definition of an abstract automaton; moreover, it has the nature of a Turing machine. The following diagram represents the definition given above. The sign is the unity of the constitutive elements:



Representamen: that which represents. Object: that which is represented. Interpretant: the process of interpretation
Fig. 1

By no accident, the semiotic levels at which sign processes (semioses) take place are the levels identified in computer science as syntax, semantics, and pragmatics. These notions originate in modern semiotics.

Syntax: the relation between signs, how signs are constituted
Semantic: the relation between sign and object, what the signs are conveying
Pragmatic: the relation between signs and the user, what for signs are used (cf. Ch. Morris)

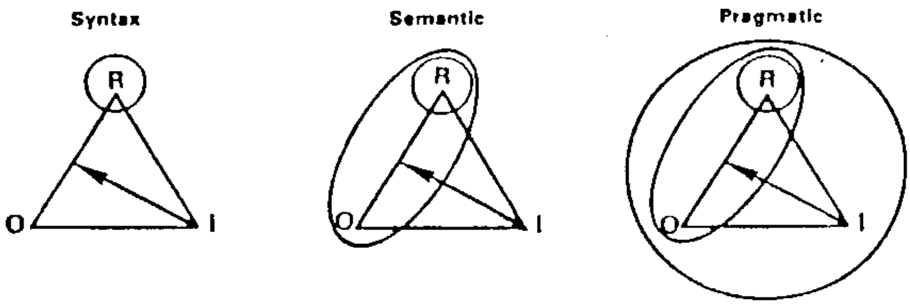
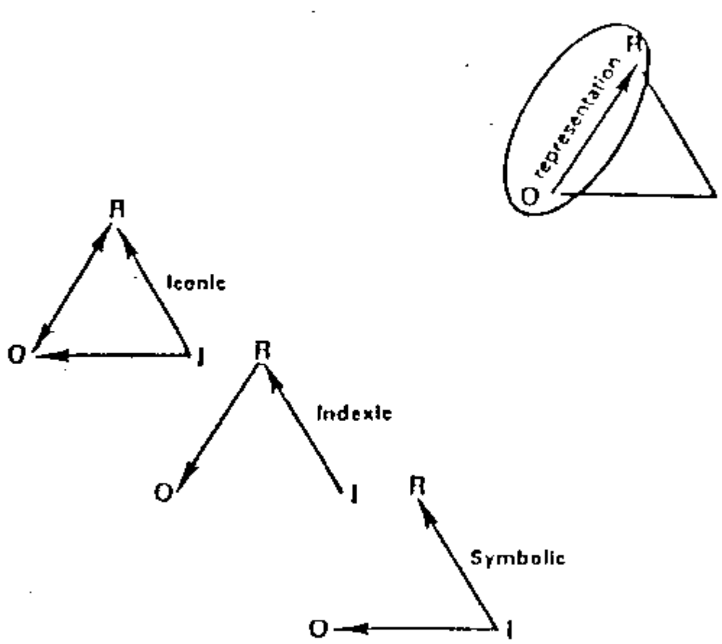


Fig. 2

There is little trouble in understanding from this that no sign can be considered independently of its relation(s) to other signs, be these similar (such as words in a given language) or different (words, images, sensory perceptions). The interdisciplinarity of semiotics is the consequence of the fact that sign processes are heterogenous by their condition, and that in order to understand how different kinds of signs constitute interpretable strings or configurations, we must acquaint ourselves with each different kind, as well as with the principles governing human or machine interpretation of such strings or configurations. Representation of an object, and the consequent interpretation of such a representation can take three different forms.



An object can be represented:
Iconically: representation based on likeness
Indexically: representation causally influenced by the object, such as a mark of the object
Symbolically: representation based on convention

Fig. 3

Once these concepts are understood, it becomes clear that the semiotic approach can serve as a general theory and methodology of the visual from the perspective of its generation, interpretation, and use. Engineers and computer scientists should have no difficulty in grasping the multi-faceted nature of the visual sign. Indeed, we look at images and associate them with other visual representations, with words, sometimes with sounds, and even to taste and to smell. In a frequently quoted answer given by Einstein [2] to a questionnaire put together by an excellent mathematician named Hadamard, we find an intriguing reference to the semiotics of the visual:

> The words of the language, as they are written or spoken, do not seem to play any role in my mechanisms of thought. The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduce or combined.

The sign operations as we know them (substitution, omission, insertion [3]) are also the main operations of the mind. Quite often, new hypotheses are visually formulated in diagrams, in graph or vector form, or in other visual representations. Problem solving follows a similar routine. We do not yet know why visual representations occur so early in the problem solving process. But we know that, once established, they constitute a path. The multiplicity of relations brought forth in images, as well as the ability of the human object to deal simultaneously with several images, should make us aware that the realm of the visual is not one of precision but of expressive power.

In the dynamics of thinking, the visual usually plays the role of a trigger, while the word acts as a filter. We learn social "seeing" from the shared images of our environment, and nature, from the shared images of our culture (architecture, clothing, shapes of tools, the mass media). We learn “professional" seeing through the specialized images pertinent to our work (conventions of visual representation in technical drawing, conventions of 3-D representation, of computer graphics, etc.). From both, in their interaction, we form new cognitive attitudes. Stereotypes are part of the process; but so is the critical awareness that makes us attempt to overcome them. As a semiotic process, visual thinking captures dynamic qualities difficult to expressively quantify in words. As kernels of our progressive understanding of phenomena, images constitute a testimony to the process of understanding.

Computer graphics is sometimes only a means of analyzing complicated data. Other times, it is a way of conveying plans to those who will build new devices or some machine components. It can serve various functions (expressed through the image's pragmatics) and can be the result of different ways of designing. Visual thinking goes beyond words or formulae. It is a way of associating images previously used or non-existent in the past. Like any other form of thinking, it allows for cognitive processes through which our mind and sensibility continuously challenge what is available or whatever has not yet been challenged. Thinking—the most complex semiotic process--involves analytic instances, synthesis, and a variety of hypotheses (abductions). The heuristics of visual thinking is quite different from any other heuristics, especially because of the particular nature of visual signs. In our approach to using computers for visual processing, it is no surprise that we go through an immaterial stage defined as 2.5-dimension. The sequence is: image (real 3-D), sketch (2-D), 2.5-D. and 3-D object representation. The 2.5-D is a necessary step between unfinished (hypothesis) result of visual thinking and the final expression of designs in 3-D. An arrow is a 2-D example of an iconic representation (of a 3-D object) that allows us to identify how planes (2.5-D) are oriented in space. The convention of motion representation also takes place in 2.5-D.

Orientation dependent upon descriptions (indexical signs)--very important in computer graphics--takes place in our visual thinking with the contribution of motor representation. Assertions are made in respect to local values (orientation in respect to natural space coordinates, especially proximity) and to global values (context). Accordingly, the indexical sign turns into a symbol (e.g., perspective representations, intersections, boundary descriptions through hard or soft edges). Drawings do not translate visual thinking. They are “sentences” from a much broader "text," sometimes unfinished. While the syntax of images is the only way through which we can acknowledge their formal status, the semantics of an image is quite often misleading.

To make a point about how the eyes integrate received visual information, *Gestaltists* refer to images in which we can see either a rabbit or a face, a young face or an old one, a vase or two identical human shapes. They fail miserably when it comes to explaining the cultural nature of these paradoxical images. To "see something" (i.e., to recognize) while looking at an image implies an experience (semantic in nature) with that image, i.e., with whatever it represents, or with some culturally shared notion of it. Even the well known figure-ground separation happens within a culture that shares the conceptual experience of figure and ground. In other words, it is necessary to understand that the *natural* aspect of images is not a proof that images are more natural than words, sounds, textures, or any other sign that people use. Once this becomes clear, visual thinking is no longer a distinctive mark of a person--some have the talent, some do not--but the result of a certain education, i.e., of a precise, specific semiotic process.

Human beings can learn visual thinking. It will not substitute other forms of thinking; it could complement them or serve specific purposes. The ability to visualize is not necessarily the result of visual thinking. Programs can be written to visualize data that the human mind cannot grasp. In such case, the underlying principle is "translation" from one system of signs to another, while respecting the integrity of the relations among data. Aware of them or not, humans deploy certain semiotic strategies in perceiving and interpreting images. We do not yet have a precise idea of all these strategies. Those that we are aware of prove useful in generating computer graphics. Others are definitely not (either because the technology does not allow for full implementation or because the visual is so strongly connected to non-visual sign processes that when it is isolated, the strategy of interpretation loses some of its efficiency). Consequently, a more in-depth study, focused on the semiotics of the image and all its ramifications, might allow us to better understand the nature of visual thinking and to apply the knowledge gained to visually oriented activities such as computer graphics.

References

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3. Mihai Nadin. On the meaning of the visual: Twelve theses regarding the visual and its interpretation, *Semiotica,* 52-3/4. 1984, pp. 335-377.