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# Cognitive aspects of visualization

There are many issues involved in how people represent data visually and how they interpret visual representations that remain, to a large extent, unresolved. A very long tradition of psychologically based explanations precedes us as we become more and more concerned with images.

Visualization—which of course takes advantage of the increased computational resources at our disposal—is by no means a new phenomenon. Images have been a constant presence in human activity down through history. What is new is the fact that in our time we can identify a systematic domain for the application of images in activities as diverse as knowledge acquisition and information dissemination, including information of trivial or casual significance (such as advertisement and political imagery). This systematic domain emerged as it became possible, and indeed necessary, to establish a conceptual framework for the many possible uses of computer graphics and related technologies for image synthesis.

If nothing else could qualify my remarks at this colloquium, I can repeat—for a record less important than the substance of the effort—that I probably taught the first recognized class in visualization, during my appointment as Eminent Scholar of Art and Design Technology at the Ohio State University, working with the Computer Graphics Research Group. The very word visualization—used before De Fanti and his colleagues applied for the first grants in the domain—caused students and faculty to wonder what it meant. This fact aside, my involvement with visualization has indeed come about through my continuous interest in cognition: How do we get to know things? Why do we know them? What do we do with our knowledge? Based on these questions (and quite a few others), I prepared for my lecture today an interactive presentation that comprises 3 levels:

1. a structural model of human interaction
2. a timeline of means and methods pertinent to human interaction
3. a synopsis of cognitive models pertinent to visualization (but not only).

Obviously, a lecture is a sequential presentation. It almost always unfolds along the dialectical path of submitting a thesis, of confronting it with antithetical viewpoints, and of finally reaching a synthesis (authentic or not). In this condition, a lecture is quite different from an interactive multimedia interaction. This is why my short remarks cannot and should not be isolated from the live interaction, in a context of non-linear association occasioned by the multimedia application I use. Failure to respect this premise will simply prevent the reader from constituting the meaning of this elaboration. The Web site address for the interactive presentation is:

http://www.nadin@code.uni-wuppertal.de. I do not only discuss and write about the need to overcome the centralized and hierarchic one-to-many model of education, but also practice a potential one-to-one alternative.

My focus here and now, however, is not on communication, or educational or cognitive processes. I gave these much attention in my book MIND—Anticipation and Chaos (more information about this is given on the Web site). The main subject here is: "Why do we visualize?" Based on what we might find out in looking for answers to this question, another arises: "How do we evaluate the efforts of visualization?" Without addressing these questions, we will continue to produce images that are expensive and, to a great extent, inappropriate. But we will not learn why, between effort and outcome, the gap is as deep as it appears to be at times. We will also continue to automate procedures for visualization which might support a more productive generation of images, but by no means the quality we need to achieve in order to meaningfully use these images.

Regardless of whether they are the outcome of visualization efforts involving computers or the simple drawings made by children, images are means of expression and communication. In this respect, the interactive presentation defines a framework: from a structure defined as one-to-many (think of cave drawings, religious icons, TV programs, for example), to subsequent structures of one-to-one and many-to-many. This framework defines ways in which we interact in practical endeavors.

[Figure 1]

The main body of arguments regarding this issue can be found in my new book, The Civilization of Illiteracy. I will summarize: Successive pragmatic contexts reflect the nature of human interactions in practical activities that support human existence. Language emerges in a pragmatic context in which images no longer remain the bearers of information essential for diversified practical effort. Characteristics such as sequentiality, linearity, determinism, centralism, and hierarchy, are eventually embodied in tools and methods that make possible levels of human efficiency appropriate to each scale of existence and interaction. Language distinguishes various practical endeavors, and through literacy it becomes a constitutive framework for subsequent activities. It represents but it also forms or constitutes. The unity between these two functions is essential for understanding why practical endeavors, regardless of their different nature, require alternative means, in particular images.

The current shift from a language dominated practical experience to visually supported activities needs to be understood in connection to the configurational nature of images, non-linearity, non-determinism, and decentralized structures of non-hierarchic nature. Distributed tasks and complex integration are made possible by multilayered mediations, the most important of which are computer-based. In the timeline of means and methods (cf. the interactive presentation) one can see how this shift is embodied in artifacts that range from the quipus of the Incas to the parallel computers and neural networks of our days.

The synopsis of the cognitive models is even more telling. As various thinkers have tried to understand how we know what we know, they have also produced testimony, sometimes of powerful expressive significance, to what we assume happens when we see something, or when we make something visible. Please examine

images documenting the perception of stars in Chinese culture, Descartes' perception drawings, and Leibniz's dyadic language. This is not merely a documentary exercise. It constitutes cognitive frames for our understanding of how thinking about images is related to what people do with images, and how they generate images.

The notion of constitution brings us to the constructive horizon of today's cognitive models (and to the names Maturana, Varela, Winograd, Flores, among others). If we do not understand their rational focus, we will not progress in making visible things nobody has seen before. Indeed, there are many ways to visualize knowledge, and some turn out to be better than others. The aesthetics that underlie images is one factor; design is another. But of fundamental importance is the semiotics of images; or better yet, the semiotics of the relation between images and other sign systems.

While it is probably impossible to reject the notion that images are more intuitive than words, and that we are naturally closer to what we see than to what we express in language, this does not mean that the visual is less difficult and less demanding than literate expression. But exactly what prompts the need for images—to capture what words cannot, and to increase the efficiency of practical endeavors—also prompts the need for understanding how images function. Not everyone with a camera in his hands produces good photographs. In order to take a good picture, one has to distinguish between the relevant and the less relevant; one has to see what others do not see or are not aware of. To see, in this sense, requires that we educate our seeing. By extension, we can say that to visualize requires that we learn how to extract shapes, colors, contrasts, visual rhythms, etc. from data and to present them for meaningful interpretations in practical contexts.

While it is true that chaotic processes have actually been evinced through visualization, it is by no means granted that bad visualization would achieve the same result. Attractors were probably indicated in some visual manner long before we understood what they were. But only as we learned how to program the visualization of dynamic systems did they impress new cognition upon us. The DNA perspective is fundamentally based on our ability to see, but we are yet to visualize the complexity of this fundamental cognitive model. Many practical endeavors, from the synthesis of new materials to nanotechnology, are based on our ability to visualize. Please understand the difference: to visualize means more than to illustrate. It also entails more than a static one-to-one mapping.

In the relation between precision—characteristic of quantitative aspects—and expressiveness—characteristic of qualitative aspects—the compromise leans heavily on quantity. The sciences, however, often reach the limits of quantitative relevance and become literally choked by data. The shift to quality is reclaiming many scientific domains, from physics (e.g., the first seconds of the universe) to biology, neurosurgery, not to mention the entire domain of virtual reality. The balance between precision and expression is a fundamental issue for any serious scientific approach today. The richer our realm of definitions (at at the pixel, voxel, etc. levels), the more subtle the capture through visualization of dynamic qualities becomes.

And so, in this spirit, allow me to advance, together with my general view on why and how we visualize, a very concrete proposition: Computer graphics education, and in particular education regarding computer visualization, ought to integrate a design component. This component will bring into focus precision and expressivity, aesthetics and semiotics. Unless and until this is brought about, we will advan-

ce slowly, on parallel paths to what ought to be our common road to knowledge access. It must no longer be that designers learn to program—which they have, doing quite well in the computational posture—while future computer scientists do not feel the urge to acquire knowledge of the design process. The majority of programs pertaining to and utilizing images are written by excellent computer scientists who are ignorant of aesthetics, semiotics, and the fundamental issues of design. Their programs are not only an offense to the eye, but, more importantly, they never reach their potential.

On a broader scale, I advocate giving visual and audio education the same attention that literacy receives in the education of the young. Now that the time of once-and-for-life education is over, the not so young should take advantage of learning more about the aural and the visual. Moreover, I plead that we integrate multimedia in education as well as in research. The sooner we start, the better. Design, in its computational form, for which my chair in Computational Design—the first and the only one of its kind in the world—stands, provides the elements pertaining to computer-based data processing, aiming at new sources of knowledge, better means of interpretation, and improved communication.

Please pay attention to the visualizations integrated in the interactive presentation. They transcend static visualization. With the addition of motion, tone, and narration, they facilitate better access to knowledge. The contributions of the Computational Design Program in this direction are focused on high-end animation—in which we can claim a leading position, and not only in Germany.

After all, the civilization we are establishing is based on abilities and competence above and beyond literate means of expression and communication. The conclusion that there is no alternative to this broad program of education and research could well result from your own interactive investigation of the accompanying interactive multimedia presentation. It is posted on the Web, but, as our civilization itself, it is still, and always, in progress. Your own contributions are welcome.