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Images in NanoScience/Technology

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Abstract. TIVs essay explores what it means to see and how contemporary technology is changing the tools and the methods of the way we perceive. The widespread desire for effective scientific visualization along with increasing sensitivity to popular attention has created a reckless culture of image manipulation. Scientists, illustrators, and artists take broad license in how they manipulate images to their purpose, but few viewers are aware of or alerted to what has been changed. The resulting images are often, unintentionally, more confusing and misleading than helpful.

Introduction

Images are playing a significant role in the development of nanoscience/technology. These images are also chi;lnging what we mean by and understand about seeing. Like the tremendous effect of the camera and photography, algorithmic microscopy is changing the culture of what we mean when we say 'see'. The images are no longer a reasonable extension of our eye and are forming a fundamental change in both the physiological and perceptual aspects of what it means to see.

People are surprised and suspicious when an artist ventures into the realms of science and technology. Humanists are suspicious of an artist interested in science and scientists don't trust artists. The arts, however, have a long and renowned tradition of creative curiosity in scientific development and a strong interest in culture. Obvious examples include the Renaissance investigations of Leonardo, paintings such as Rembrandt's' Anatomy Lesson', and popular speculation that Picasso's Cubist concept, of seeing objects from multiple points of view at one instant, was an intuitive visual version of the complicated concepts of quantum physics.

This is not the popular, pedestrian art that hangs over the sofa, rather an art that establishes pathways, an art with meaning and purpose, an art that competes in a fast paced world. This awareness comes from art that, as a discipline, helps mediate complex and complicated issues for a public that is often technologically alienated. It is art that provides for alternate forms and methods of discovery. Contemporary' conceptual art seeks not only the visual aspects of seeing, but also seeing as a means of understanding. These artists typically understand the formal aspects of image presentation, but also have a sincere interest in how their images communicate with, relate to, and influence contemporary culture.

1. Illusion

Reacting in painting to the power of the camera, twentieth century artists Rene Magritte and M. C. Escher showed us how easy it is to fool or misunderstand the differences between the expectations of what we know and the 'truth' of what we see - teasing us about the difference between these realities. Magritte's painting 'Euclidean' makes us question where the painting begins and shows us how easy it is to misperceive. 'Ceci n'est pas une pipe' reminds and warns us that an image, no matter how accurate, is only a representation, not the thing itself.

Optical illusions make the potential of misunderstanding even more apparent with images that can be perceived in two distinct and different ways - a woman sitting at a vanity becomes an ominous skull ('All is Vanity', Charles Allen Gillbert). Salvador Dali repeatedly played with these dual, often contradictory concepts in his Surrealist paintings. Other illusions take advantage of the physical nature of how our eyes process information with after-images of black dots where none exist, and parallel lines that surely seem to slant. They take advantage not only of what, but how our brain translates what we see.

Some of the most interesting illusions play the left, logical, analytic hemisphere of our brain against the right, visual, perceiving half. One classic example prints the names of multiple colors in inks of differing colors. The viewer is asked to recite the actual printed color of each word; but our schooled and practiced left brain rebels, wanting to read and state the word. These also provide important lessons for images in science.

2. Microscopy

The world at the nanoscale is hard to perceive. Recent generations have become accustomed to concepts of the infinite and the vast realms of space, measuring these distances in years at the spe~d of light. The new worlds being discovered at the nanoscale are even harder to imagine - 10^{-9} meters, one billionth of a meter. To put this into perspective, a second at the speed 9,f light would encompass a distance of 186,000 miles; a nanosecond at the speed of light would be a mere eleven inches. Insightful books such as Philip and Phylis Morrison's 'Powers ofTen' take us 10^{25} meters (1 billion light years) to the vast reaches of space, but only 10^{-16} meters (0.1 femto) into little worlds previously unknown.

The nanoscale, though far from the smallest of our awareness, is unique in that it is where we find and explore the funda:mental building blocks of our lives, manipulating molecules, literally one atom at a time.

The microscopy necessary to 'see' and confirm these occurrences no longer employs optical or visual magnification. Rather, these microscopes are highly specialized devices used on samples in carefully controlled environments, usually under vacuum, and often at very low temperatures to slow the normal motions inherent in objects at that scale. They use touch versus sight, ~suaIly a mechanical stylus, probe or electron beam. The stylus reflects topological information to a reader that establishes a 3-dimesional surface map. There is a wide range of specialized, purpose specific, microscopy instruments, designed to 'see' varying specialized aspects of the nanoscale.

The resulting information is interpreted, with the help of computers, through mathematical algorithms, generating a visual image that can b.e viewed in many forms, from a numeric grid or value map to a 3-dimensional environment. The design of the instrument, the questions that interest the investigator, the skill of the operator, the information sought, the portion of the sample selected, and even the depth of focus all affect the resulting appearance. Value and color are common tools used to distinguish important or meaningful elements. The use of the latter is especially interesting in that the nanoscale is smaller than wavelengths of light, making it a colorless world.

Yet, with all this alteration, scientists and engineers tell us we are 'seeing' individual atoms. The nature of the instrument does not allow for recognition of undercuts, so atoms, which are generally thought to be spherical, are represented as organic, rather than purely geometric, cones. It is almost as if we do everything we can to confuse the image while ignoring many things we could do to make it more accurate. Shapes are constructed by carefully and selectively manipulating individual atoms on a unifonn surface.

It is even hard to find uniform understanding among various scientists and engineers regarding what portions of an image have been manipulated and how they may have been altered. Verbal descriptions usually speak more to the materials of the sample rather than the undocumented visual alterations. There is a growing need for some simple, common conventions of categorization, communication, and understanding about what the image seeks to convey and how it may have been changed.

3. Images

Many nanoscale images are colorless, visually bland versions of ordered atoms or simple surface topologies, exhibiting the ability to order or control our environment, others take extensive license in making an image that is often more visually interesting than scientifically informative - see the website, 'N anoPicture of the Day' (www.nanopicoftheday.orgl) for some of the most interesting. Break-through images such as Don Eigler's now famous corporate logo, 'IBM' attest to the ability to manipulate our world one atom at a time - albeit very slowly and at very low temperature. This was quickly followed by a competition from 'Intel' and a change of subject to representation of self in the 'Carbon Monoxide Man'. It is interesting to note that the images seem to recapitulate the development of Western art, starting with marks, images of our environment, moving to representations of self, and finally seeking more creative and visually exciting variations.

Dr. James Tour of Rice University has created a series of substantive figures called 'NanoKids', refining1a nano-figure while communicating with, captivating, and educating middle school childr~n, from whom will come tomorrow's scientists. Tour laments that many elementary school, but few high school students are excited about becoming scientists, and one wonder~ where and how the interest is lost. Th~se visual efforts in public education also become effective devices for educating their parents and mediating this information to an ever curious, and often technically naive, public.

4. Image typology

An initial typology of these varied images includes: Schematics, Documentation, Fantasy, and Fine Art.

SCHEMA TICS represent an idealized version of an image through graphs, diagrams, stick and ball models, and simulations. These are the more traditional, guarded images of scientific visualization with little visual drama. Other examples include line drawings and molecular models of the DNA spiral, or a simulation of a fine motion controller potentially used for future molecular manufacturing.

DOCUMENTATION attempts to characterize how the image really is and includes photography, microscopy, illustration, and animation. Examples range from a wide variety of nanolithography to Eigler's 'Electron Corrals'. The very nature of these topographies allow for fly-through animations, another perfect, yet uncertain postmodern manifestation. Many of these animations seem to be done simply because we know how to create them and because they look 'cool', rather than because they offer any additional insight or illumination.

Like the frenetic wanderings of the National Aeronautics and Space Administration of late, contemporary scientists feel compelled, often rightly, to interest a largely uninformed public, to assure some form of public understanding and to develop the enthusiasm that will help influence decision makers, thus maintaining a continuous flow of research dollars. But are these highly manipulated and often-inaccurate images still evidence of good sCience and the right approach?

Even the most cautious investigators believe that this science and technology will influence every aspect of our lives and be the great social leveler, but the process of development is slow, and the need for tangible results overwhelming. This balance between basic research and practical application is an increasingly contentious subject on university campuses as well as in corporate laboratories. Hopes for the rags to riches growth like that of the digital industry along with the fear of unintended and possibly illicit use complicate the debate even more.

FANT ASY includes a wide range of illustrative speculation that is not necessarily based on hard science and captivates at the risk of misinforming. Here we find a wild collection of monster-like mechanical devices, often shown in veins and arteries, attacking plaque and cholesterol. An award winning transparent 'nanolouse' uses pinchers and a needle-like probe to grab and sample a red blood cell. Another image shows two humans with virtual control over hurnan-like nanobots. The sad irony in this message is that there is little or no apparent relationship between the position of the human driver and the machines they supposedly control. These images are popular, attractive, and intriguing, but not very inforrnative and dangerously misleading.

FINE ART with respect to nanoscience seeks sorne form of meaningful and long-term effect on culture. It is, however, almost nonexistent, and leaves plenty of opportunity for aspiring young artists who dare to enter this complex field. Some well-known contemporary artists such as Gerhard Richter have utilized microscopy images from the nanoscale. Previous work in art & technology, installation, and conceptual art offer effective models for meaningful artjstic progress and development.

The general:public is mostly unaware of this rapidly developing technology, the art world perhaps even more so, potentially influenced by a fear of what technology portends. for them and a re:active desire for the warmth and certainty of the hand-made. But, who better than the arts to evaluate and mediate the cultural role inherent in these developments?

Artists can and should be involved in scientific visualization, illustration, as well as the resulting fine art. They have the ability to mediate complex information and assist in the public's understanding. Cooperative, creative and interdisciplinary work in this area also offers the opportunity for inventive visual discovery.

Nanoscale images can function in various combinations of these four categories and have the potential to change designation over time, but this outline of a typology should help us understand how an image operates and what information it intends to convey. In his book *The Structure of Art* Jack Burnham showed how an artwork can be categorized as natural or cultural and moves between these two areas as the public absorbs and assesses them over time.

Visual images in general are often misused or misunderstood, and this is especially true in nanoscience. Both popular publications and respected scientific periodicals have run dangerously misleading cover images. The cover of 'Scientific American' (June 2000) shows a molecule at the nanoscale poised between two gold tips; the individual atoms are a rich variety of colors, and show highlight and shadow - none of which exists at this scale. The gold tips show a uniform surface more in the realm of a human scale and show no individual atoms or molecules.

Similarly, 'Science' (9 November 2001, Vol. 284, No. 5545) shows neutral colored nanoscale carbon nanotubes clamped in place with the characteristics of human scale clamps and surfaces, all surfaces are replete with color, highlights, shadows, and reflections.

These sorts of misunderstandings may be even more dramatically magnified as Michael Crichton's popular book 'Prey' becomes a major motion picture with swarming nanobots mercilessly killing their creators and others. Images are powerful. Add to that Hollywood moving pictures, sound, and a good story, and the public blurs fact and fiction ever more readily. Where should we draw the line regarding responsible conveyance of informati on?

5. Conclusions

Cameras have come to be accepted as an extension of the eye and have preceded us to places we hoped to go to such as the moon and Mars. \Vhile not perfect, photography presents reasonable facts of what we trust we can, and ultimately will, confinn with our own eyes. The microscopy that allows us to see the nanoscale is distinctly different, increasing the distance between technological device and our eye, and posing some interesting questions. Will we ever be able to visually confirm these images? \What unexpected changes might allow us to actually see what is now unseen?

NanoScience is changing how we see and what it means to see. In the development of our species, we started)Yith vision; 2-D reflection was the beginning of interpretation, followed by marks, cave paintings, and continually refined illusory representation through art. Telescopes and microscopy provided for a new world of visual magnification that enhanced the resources of our eyes. Then photography offered an accurate rendering or reasonable visual truth, a significant cultural change. The camera often led where we trust the eye would follow - distant landscape, our own circulatory system, deep sea, the Moon, and Mars. Will we ever be able to confirm the nanoscale with our naked eye and do we need visual confirmation? We are generating irnages well beyond our current perceptual ability.

Digital manipuiation, which allows for sophisticated alteration of a photographic image created a loss of trust in the visual truth of photographs. Algorithmic microscopy represents a significant chiinge in the convention of seeing and requires broad trust in the accuracy of science and mathematics. While this trust may be warranted, much needs to be dorie to bridge the potential gap of understanding.

Should we fear these changes? Should we fear that humans will become obsolete and computers will take over the world? There are some compelling arguments that start in small packages - our dependence on technological devices, first for physical assistance and later for careful calculation, is subtly invasive. If we can exhibit no better control of the images supporting nanoscience, what subtle message do we send the public about our ability to control the broader development of the science?

The twentieth century artist, Marcel Duchamp sends an opportune message in 'With Hidden Noise'. An enigmatic ball of string clamped between two metal plates. We can shake the object and know there is something inside the void ofche ball of string. We don't know what it is. Duchamp envisioned our dilemma. He created the artwork, but had a friend place a secret object inside, fully aware that one can fool others, but also oneself.

As we work to communicate the power and potential of nanoscience/technology, we must also work to assure that the creative work serves a brQader interest. We must be careful not to fool ourselves, as well as an unsuspecting public, in the process.

Scientists should consider and encourage artistic participation in the popular interdisciplinary, collaborative work of nanoscience. It will certainly enhance the images and may lead to unexpected new discoveries.

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