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Title: SCIENTISTS AND ARTISTS: "HEY! YOU GOT ART IN MY SCIENCE! YOU GOT SCIENCE ON MY ART."

Author(s): M. ELISE ELFMAN
BIRCHARD HAYES
KELLY MICHEL
BRIAN BOYER

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Abstract:

The pairing of science and art has proven to be a powerful combination since the Renaissance. The combination of these two seemingly disparate disciplines ensured that even complex scientific theories could be explored and effectively communicated to both the subject matter expert and the layman. In modern times, science and art have frequently been considered disjoint, with objectives, philosophies, and perspectives often in direct opposition to each other. However, given the technological advances in computer science and high fidelity 3-D graphics development tools, this marriage of art and science is once again logically complimentary. Art, in the form of computer graphics and animation created on supercomputers, has already proven to be a powerful tool for improving scientific research and providing insight into nuclear phenomena. This paper discusses the power of pairing artists with scientists and engineers in order to pursue the possibilities of a widely accessible lightweight, interactive approach. We will use a discussion of photo-realism versus stylization to illuminate the expected beneficial outcome of such collaborations and the societal advantages gained by a non-traditional partnering of these two fields.

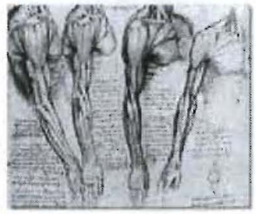
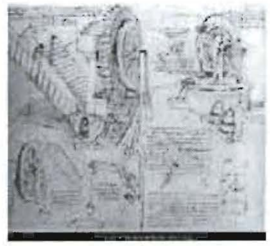
Introduction:

Science and art seem very much like warring factions, but they are inexorably linked. Numerous people have tried to quantify art and the beauty therein, from Pythagoras to Immanuel Kant. There is something artful in the chaotic arrangement of branches of an old oak tree; something beautiful in images of salt magnified two thousand times. In the twenty first century, the links between science and art are only just beginning to be explored, unified in ways that have not been seen since the time of Leonardo da Vinci.

The Renaissance gave rise to a more humanistic and secular outlook, much like today. The capabilities of the individual were more valued and sought out. During this time, artists and scientists were not necessarily separate entities. Da Vinci knew, as did his contemporaries, the value of pairing science and art, and spoke many times on the subject: "The 'art' or skill of painting must be supported by the painter's 'science', or solid knowledge of living forms, by his intellectual understanding of their intrinsic nature and underlying principles." The third element in da Vinci's breakdown of science and art was "fantasia", the artist's creative imagination.

Da Vinci understood well not only the intersection of art and science, but when to apply his imagination to better convey his ideas. His anatomical drawings are not always absolutely accurate to a dissected cadaver, but rather capture the functional relationships between different parts of the body. He used both realism and stylization to great effect in his work.

DRAFT

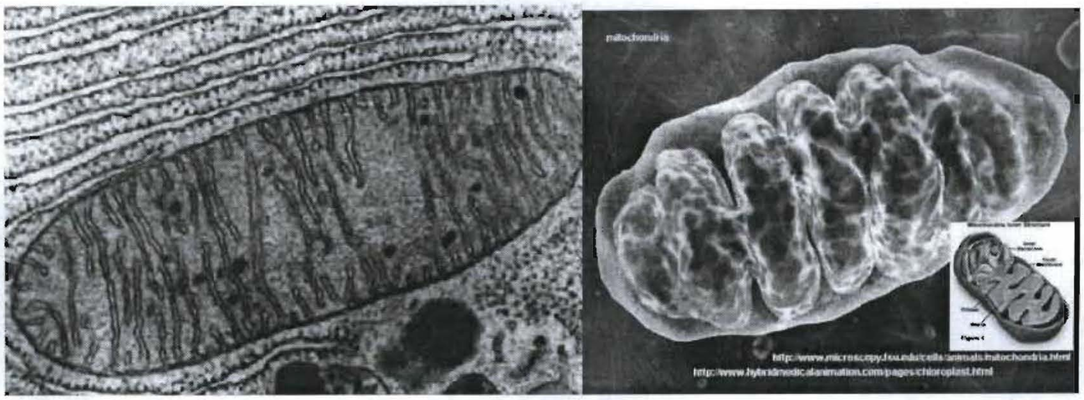
  

Photorealism vs. Stylization:

Today, the question of whether to employ photorealism or stylization depends on a number of factors. The chief factor is the type of project, and the audience for the project. An animation designed to help members or the public, who may not have a background in science, understand diversion pathways of nuclear material may be far more stylized and limit the information conveyed. The same animation intended to be shown to a group of safeguards experts could be far more realistic, both in visual style and the amount of information included in said animation. Audience and amount of information conveyed are evaluated in another way to determining the photorealism (or lack thereof) in an animation or training game.

Currently, stylization is utilized more for medical and scientific visualization, and photorealism for training and architectural visualization. Stylization is used primarily in medical and scientific visualization because of two things, the first being that often the events depicted are understood conceptually but may not be viewable in the traditional sense. With 3D visualization, it is easy to depict what is happening (the space science animations on the History Channel, for example). The Virtual Simulation Base-Line Experience (VISIBLE) team at Los Alamos National Laboratory created a short animation about the effects of a HANE on the magnetosphere. Were such an event to take place, the data would reflect the wave running from pole to pole, as depicted in the animation; however, in real life the space surrounding the earth would look the same as before. It is a visually unobservable phenomenon. The second thing that urges medical and scientific visualization toward stylization rather than photorealism is that a photorealistic image does not always convey information in a consumable way. In 3D one can see the way mitochondria are truly shaped and act, or examine the flow pattern of material within a cascade centrifuge much more easily than a two dimensional diagram allows.



The Uses of Collaboration:

Separately, artists, engineers and physicists have all performed excellent work in connection with and designing more robust nuclear safeguards. Artists have developed graphics and mock-ups of and for nuclear facilities, physicists have modeled algorithms explaining the behavior of nuclear material, and engineers have written complex scripts to drive gaming engines. It took all three of these disciplines to create a functional virtual model of a TSA portal. An artist created the portal and its inner workings, a physicist provided the algorithms to correctly represent the gamma and neutron particles as they were emanated by a radioactive source within the game, and an engineer tied the two together to create a working simulation. The resulting whole was far greater than any of the parts.

Similarly, it took these varying disciplines to create a new kind of safeguards-by-design training game. Again, artists created all the physical workings of game, and physicists provided the necessary data to accurately represent the nuclear material therein. An engineer united those two elements, enabling the player to pick up a source under water and move it to a container to swap out the rods. It was a former NASA space scientist that asked "Why don't we include a drag and drop system to test differing positions of portal monitors and other safeguards?" The drag and drop system of object placement is not new; it is as old as the game *The Sims,* however it has not yet been utilized in safeguards by design. It is a powerful new way of testing a facility portal setup, and is accurate because it has real science powering the virtual portals.

Of course, the previous example could have been done with simpler graphics, perhaps done as a two dimensional Flash cartoon instead of near-photorealistic 3D. However, another photorealistic facility model proves the true power of 3D for nuclear safeguards. The VISIBLE team modeled Idaho National Laboratory's CBR II. It was volumetrically correct and included realistic placement of emergency lights, fire extinguishers, and safety signs, as well as the general "stuff" of the working laboratory. Upon completion, it was demonstrated to a group of people who then visited the real world facility. They were shocked. They said they felt as if they had already been in the building, and could navigate the real world facility by landmarks that they remembered in the game. If nuclear inspectors could have this kind of familiarity with a facility they

DRAFT

have never previously entered, it would reduce dosage and increase their effectiveness at identifying hazards and diversion pathways. With this technology, it is completely possible to achieve that.

Supercomputing has been used to demonstrate the experimentally unobservable to improve hypothesizes, such as the discovery that edges of a film of silver crystals gets smoother below 200 degrees Kelvin, rather than rougher. It has been used to improve industrial designs, such as using supercomputing to examine the process of riveting a bolt to a piece of metal by Boeing, which took the ensuing data and created a better rivet. It has been used to model the expansion of matter in the universe as well as fluid dynamics. All of these vastly different disciplines turned to supercomputing in the hopes that they could visually understand something they could not otherwise, in effect desiring to see the art that is the universe in action. Though supercomputers deal with far more information than a training game on a laptop, ultimately they endeavor to achieve the same thing: visually express a set of ideas for the purpose of increasing knowledge.

Why Games:

Social learning theory states that people learn from observing models and mimicking their behavior. Games are the ultimate delivery system of this kind of learning, aside from real world experience, which is extremely costly in dollars and potentially lives. Surgeons who use training games are 29% faster and six times less likely to make mistakes, and training games have been used in the FBI, CIA, and DEA as early as the 1990's. More recently, a photorealistic Iraq-based version of the game *Neverwinter Nights* was used to train soldiers. It appeared to be an incredibly effective training delivery system, until command realized the participating soldiers were learning a technique incorrectly.

Negative training, or training that does not accurately depict the way to achieve a technique or goal, must be avoided. This is achieved by extensive research into the depicted action and often speaking to real world experts. It requires planning, but is easily realizable. Negative training is another aspect to consider when deciding if a project should be photorealistic or stylized. Most training games can be created in varying

DRAFT

degrees of stylization without risking negative training, but occasionally (such as in flight simulation) photorealism is the only solution.

This kind of photorealistic training device has already been implemented in the world of nuclear safeguards. Los Alamos National Laboratory is responsible for conducting Radiation Review analysis software training. At the end of the training course, students perform a practical exercise to test their ability to detect mistakes by operators in the handling of nuclear material within a source safe. Three years ago, a virtual training game was introduced. The game featured a mock facility, able to find gaps between tables and walls, areas of the room cameras could not see, and more. Student scores for the practical exercise, prior to use of the training game, averaged 60-65% correct. After utilizing the game, average student scores increased to 90-95% correct. Training games for inspectors are inarguably effective, as is the relationship between engineers and artists which produced this highly effective training device.

Conclusion:

Training through gaming is the quickest and most effective mechanism available today. It is fortunate for the nuclear industry and safeguards alike that the instruction tools of today are looking back to the intersection of science and art of the past to create beautifully useful tools. Thanks to the pairing of art and science, those tools will lead to a future of highly effective, low cost training implements.

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DRAFT

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