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Abstract

The author is a Professor of Design and has successfully collaborated with computational scientists on data visualization projects for over 22 years. Data-driven scientific visualizations permeate culture and have become important tools for science discovery and public outreach education. The author provides a history of successful "renaissance teams" collaborations where artists have played a major roled in the process of scientific visualization. The outcomes have been measurable and lead to some generalizations about interdisciplinary collaborative projects.

Introduction and Prior Work:

In its broadest sense, visualization involves the process of making the invisible visible. It has been an important human activity for tens of thousands of years. From cave paintings to virtual CAVE™ environments, the process of making the cognitive imagination visually tangible using culturally-dominate technologies is one of the most consistent behaviors of human kind. Dominate technologies ascend with time from Paleolithic carving tools to modern digital information technology (IT). Modern IT visualization is a way of organizing the incoming "kaleidoscopic" flood of data. Data is typically defined as a system of numbers that provides measurable, quantitative information. Scientific computational models, instrument sensing, geographic, statistical, and contextual information comprise data. The scientific visualization process employs IT to transform scientific simulation data into digital representations or visual models.

Scientific visualizations permeate society and have become an important part of visual culture. Large audiences view them on television, movies, and planetarium shows. Well-respected scientific journals such as "Science" and popular magazines such as National Geographic regularly feature data-driven visuals. Scientists and decision makers routinely employ data-driven visualizations. They are powerful informants due to the scientific and technological authority that they wield. This paper argues that creative practitioners have a great deal to contribute to this process and that interdisciplinary collaboration is a key component to successful outcomes.

In 1985, Professor Donna Cox began to organize "Renaissance Teams"at the NCSA-UIUC [Cox 88A]. She coined the term "Renaissance Teams" to describe multidisciplinary teams of experts focused on solving visualization problems and provided a guidelines for successful collaborations at ACM Special Interest Group on Computer Graphics (SIGGRAPH)[Cox 88B]. These guidelines are still relevant to current discussions about synergy among creative practice, collaboration and IT. Extracted guidelines are summarized here:

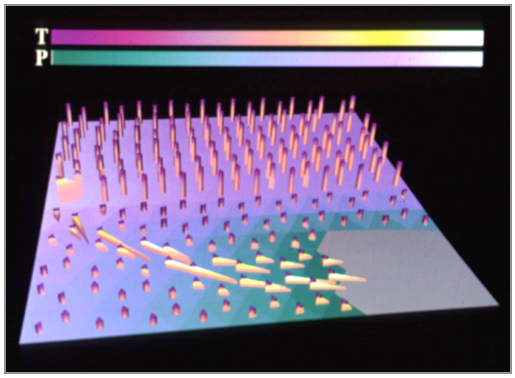
Renaissance Teams

Renaissance Team is a group of interdisciplinary specialists who interact to enlarge the problem-solution domain and provide technological, analytical, and visual synergism in the quest for knowledge and information discovery. Teamwork requires a non-trivial psycho-strategy. Here are some codes of behavior for successful teams.

1) There must be a common, passionate goal for the team members
2) Members must have mutual respect for each other member and his/her discipline
3) Each member must be willing to learn from other members of the team
4) Each member must recognize other's intellectual territory
5) The team should not have too many members
6) The team must continually check to make sure that the research problems are getting solved or attended
7) Members must not become over-committed to other projects
8) One person must carry the flag for project as a champion and coordinate efforts
9) Each member must be credited and given his/her recognition when the project is presented or publicized
10) Each member must get something out of the project which is personally rewarding and tangible

Cox has collaborated with scientists, engineers, and technologists to create new technologies and visualization products. Renaissance Teams include many skills of the artist: production, direction, design, color, and editing. In many cases, the artist leads the technology or innovation. For example, Cox and research artist, Robert Patterson, NCSA, created the first data-driven visualization of the NSFnet. This image is one of the most popular data visualizations of the early internet. The public continues to request this iconic visual showing the enormous growth of the national network from 1991-1993 [Figure 1].

[Figure 1] The color map indicates flow of network traffic measured in millions of bytes.



[Figure 2] First 3D visualization using glyphs, computer graphics animation and two color transfer functions to show plastic injection molding.

Cox collaborated with Dr. Richard Ellson, Kodak Research Scientist, to create the first 3-D data-driven computer graphics representation of plastic injection numerical simulation (Cox 88B). Figure 2 shows the unusual but useful representation of the numerical data. The 'glyphs'

represent temperature, pressure, and velocity of the data. In the 90's, Cox brought this type of project-based collaborative approach to the classroom through experimental courses designed to teach the collaborative process. She presented this methodology in an EDUCOM keynote address. Collaboration and project-based learning are key components to this educational philosophy that encourages creativity in the classroom. Collaboration is also a key component in many large-scale projects.

In 1994, Cox was Associate Director for Scientific Visualization and Art Director for the PIXAR/NCSA segment of a large-scale film project. "Cosmic Voyage," an IMAX movie about the relative scale of things in the universe, was nominated for an Academy Award in 1996. This IMAX film continues to educate the public about the universe. The advanced technologies of supercomputing and visualization were employed to artistically render images of galaxies colliding in swirling paint-like effects. This movie was unprecedented in the use of scientific visualizations instead of special effects.

Figure 3 The cutaway view of the digital dome in the Hayden Planetarium at the American Museum of Natural History in New York City

Virtual Director

In the making of "Cosmic Voyage," Cox, Robert Patterson, and Marcus Thiébaux, then a student at University of Illinois created Virtual Director™. They patented this software framework that provides a virtual choreography and navigation system to enable users to see and control the virtual camera in 3-dimensional stereo, to record frames and to preview the recording on virtual screens. Virtual Director™ also provides capabilities to collaborate over the Internet so that users can interact together even though they may be located at great distances from each other geographically. To create the following shows and exhibits with the Hayden Planetarium, the NCSA team used Virtual Director's remote virtual collaborative capabilities over the Internet2: from the University of Illinois to the New York City digital dome (see Figure 3). The NCSA team worked from Illinois and collaborated in real-time with the Hayden Planetarium artists and scientists to design, choreograph, and render virtual experiences through data-driven scientific visualizations.

Hayden Planetarium

The NCSA team has collaborated to create two "space" shows in the large upper digital dome and the Big Bang Theatre exhibit located in the lower section of the digital dome. The first "space" show was called "Passport to the Universe," narrated by actor Tom Hanks, opened at the Millennium 2000 New Year's donor celebration. The second "space" show, "The Search for Life," narrated by actor Harrison Ford, opened February 2002. Both of these high-resolution, digital shows are exhibited in the upper hemisphere of a large digital dome (over 9 million pixels), which provides an immersive experience to 440 people during each 17-minute show. Millions of people have seen these science education shows in the last few years.

In addition to museums and planetariums, the NCSA team also developed visualizations for broadcast television shows. They produced visualizations for the High-Definition (over 2 million pixels) Television Public Broadcasting System (PBS) NOVA/WGBH show, "Runaway Universe." the author was Producer and Art Director for the NCSA visualizations for this 1-hour special. The team created over 17 scenes of scientific visualizations using data from five scientists.

IntelliBadge™

IntelliBadge™is another collaborative arts and technology project funded by IEEE and NCSA. At Supercomputing 2002 (SC02), November 16-24 at the Baltimore Convention Center, in Baltimore, Maryland, U.S.A., Cox and team developed a system for location tracking and real-time digital visualization. About 1000 conference attendees volunteered to carry Radio Frequency Identification (RFID) tags during the events. Real-time visualization of attendees showed the flow patterns during the conference. This system included a real-time database, interactive and playback visualization software, and a web application. Participants were then able to log into the system to check statistics and gather information, either at the kiosks or remotely through the IntelliBadge™ website.
Figure 4 & 5 IntelliBadge™ data visualizations

Figure 4 Data on bar graphs

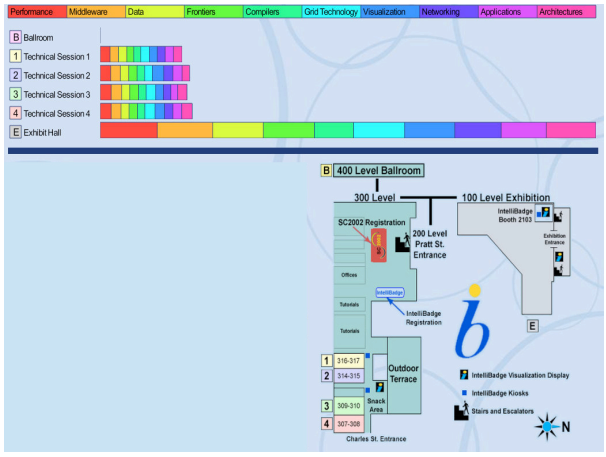
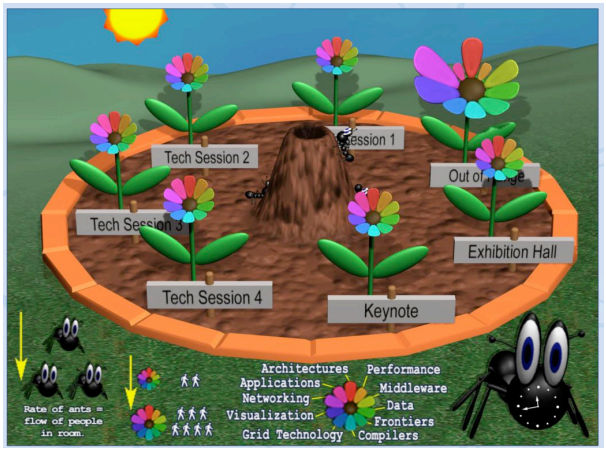


Figure 5 Novel Visual Metaphor with same data



conventional to unconventional visual metaphors

Several visualization schemes were used to show the flow of people at the conference. A scheme called "How Does Your Conference Grow" provided a garden metaphor with each flower

representing a conference event room (see Figure 5). Each flower scaled according to the number of people in the room and its petals grew or shrank as people entered or exited the rooms. The rate at which people flowed in and out of the rooms was represented by the rate of ants entering and leaving the flowers. The real-time visualization of the data of people and their interests moving throughout the physical space employed similar techniques as the other data-driven visualizations. The garden metaphor was in great contrast to other more conventional visualizations such as animated bar charts (see Figure 4). Artists can contribute to new perspectives and new ways of looking at data, generating new visual models and novel ways of representation.

The Black Holes Project

The "Black Holes Project" was a partnership among Thomas Lucas Productions, Denver Museum of Nature and Science, NCSA, and ES/Spitz. The National Science Foundation (NSF) funded a grant [NSF proposal ISE Award #0337286 http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0337286] for the Project. The grant Principal Investigator is Tom Lucas, with three co-Principal Investigators: Donna Cox, NCSA; Dr. Andrew Hamilton, Astronomer at University of Colorado; and Joslyn Schoemer, Denver Museum of Nature and Science. These investigators proposed a suite of media that explores the contemporary science of black holes. The media products includes 1) a full-dome planetarium show titled Black Holes: The Other Side of Infinity (to view a trailer go http://www.nsf.gov/news/now_showing/film/black_hole.jsp;http://www.dmns.org/main/en/Professionals/Press/CurrentPressReleases/Press+Releases/Planetarium/blackHolesImagesPress.htm); 2) one-hour NOVA program titled Monster of the Milky Way (to view the program go to http://www.pbs.org/wgbh/nova/blackhole/).
and 3) a website with customized activities and sequences, links to related sites, outreach materials and supporting resources for teachers and informal educators. The key staff in the production is Tom Lucas, with the responsibility as the overall Director of the NOVA and planetarium shows; Donna Cox co-Producer of the NOVA and planetarium show and Director of the data-driven scientific visualization; Jodi Schoemer, Executive Producer of the planetarium show; and Dr. Andrew Hamilton, Science Director of the planetarium show.

Measurements of Success

1. "Cosmic Voyage" was the first science educational IMAX film nominated for Academy Awards in the documentary short subject area. It was the first time that computational science had been featured in an Academy Awards nomination.
2. The Virtual Direct ™ was awarded a patent (COX, DONNA, ROBERT PATTERSON, and MARCUS THIEBAUX 2000)
3. The summative evaluations from the Black Holes planetarium show & the PBS NOVA show indicated that audiences were both impressed with visualizations, that they learned major scientific concepts and that they were entertained.

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