GVE ’99:
Report of the 1999 Eurographics/SIGGRAPH Workshop on Graphics and Visualization Education

Steve Cunningham
California State University Stanislaus*

The Graphics and Visualization Education Workshop (GVE ’99), held July 3–5, 1999 in Coimbra, Portugal, was a jointly-sponsored event of Eurographics and ACM SIGGRAPH and was partially supported by the National Science Foundation. It was chaired by Werner Hansmann, University of Hamburg (Germany), Mike McGrath, Colorado School of Mines (USA), and José Teixeira, University of Coimbra (Portugal). It assembled 44 colleagues from twelve countries to consider the future in computer graphics education. Among the workshop themes were curriculum for computer graphics in computer science and in art, development of computer graphics for teaching, media, interaction, and collaborations between disciplines and institutions.

The workshop was organized as a working event to give all the participants the best opportunity to talk with each other and develop ideas along the themes above. Participants were chosen based on position papers submitted to the workshop organizers, and a small number of participants were chosen to present their papers as a way to get particular ideas into the discussion. Mike Bailey of the San Diego Supercomputer Center was keynoter for the workshop, and Jack Bresenham of Winthrop College summarized the discussions of the workshop in a closing presentation. This note reports the workshop results as developed by the working groups by the end of the workshop. Complete information, including more condensed reports and the participants’ developed position papers, is online at

`www.eg.org/WorkshopReports/GVE99/`

and

`www.education.siggraph.org/conferences/GVE99/`

Overview

In the professional lifetime of many of the participants in the workshop, computer graphics has grown and changed immensely. It has gone from a wonderfully interesting and challenging subject looking for applications to a broad-based, mature, intellectually accepted subject with its own body of theory and practice whose applications lie all around us. As part of this growth we have seen computer graphics become affordable and have seen sound and usable standards emerge.

The challenge in computer graphics instruction, then, is a challenge of dealing with the greater maturity in the field and the growing expectations of the world, serving both our discipline and all the areas that use our discipline, while maintaining a fundamentally sound approach to our field. Alongside this challenge is the challenge of building a view in our institutions and among those that fund educational development that supporting computer graphics is a sound investment in developing the entire intellectual growth of all the areas where graphics is used. It is time that we determine what the next step in computer graphics education is and take that step towards understanding the challenges of education in the changed environment of computer graphics.

The workshop focused on looking ahead at the way computer graphics education can respond to these challenges, both in teaching computer graphics itself and in the way computer graphics can contribute to other areas’ education. The workshop was organized to have a minimal number of presentations and to focus on discussions in self-defining working groups. That is, from the submitted position papers the workshop organizers identified a small number of common areas of focus, and the participants were invited to join working groups based on the match between their interest and these areas, or to define new working groups with a different focus. Each working group defined its own view of the challenges above and responded with an individual report. These reports make up the remainder of this article.

Computer Science

The discussion of computer graphics in the computer science curriculum began by considering introductory computer graphics courses for computer science majors. This working group considered the job market, prerequisite knowledge, and skills students should acquire in this introductory course. While the group focused on the technical content of computer graphics courses, it is clear that students need communication and management skills, social skills to work in groups, a sense of esthetics and visual communication, and the ability to learn independently. Most of these needs are shared by the general computer science student and computer science programs are encouraged to ensure students have the chance to develop them.

In the technical area, in spite of many changes in the way computer graphics is done in the computer science world, the rendering pipeline continues to be of enduring importance. Its treatment will, however, vary depending on the course goals. If a curriculum can offer only one graphics course, the working group suggests that a good course model is to take a top-down approach using a high-level API, with instructors examining selected aspects of the pipeline (modeling, viewing, rasterization, display) in detail. The course should carefully balance the presentation of technical material through lectures with focused laboratory work and with well-designed projects. Laboratories or projects can be used to make a course serve local needs or particular groups of students. In general, textbooks for such a course are seen less as primary sources of information than as backup resources that students can use for reference.

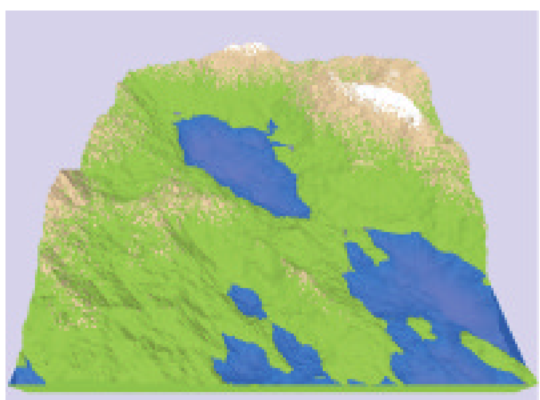

Figure 1: an image from a student program

The primary focus of the working group was the first course in computer graphics. The group discussed the kind of software support that would be appropriate for this course, and as noted above suggested that the course is probably best based on a solid API. The group also discussed the nature of the course, and agreed on three primary features that this course should include. First, this course should strongly emphasize three-dimensional graphics. Particular local needs may suggest including two-dimensional topics as well, but the earlier approach of beginning with 2D topics and moving to 3D seems to be outdated. Second, this course should emphasize interactive techniques for computer graphics. While there are clearly important non-interactive graphics applications, the introductory graphics course is an excellent place to introduce event-driven programming, as well as the kind of graphical object selection and simple interaction techniques that are important components of our field. Figure 1 shows an example of an image created by a student's interactive 3D graphics program. Third, this course should place an emphasis on the visual aspects of computer graphics. Unlike most of computer science, algorithm analysis in computer graphics must not only consider space and time aspects, but also a user's perception of the output in the context of the user's goals. Students should learn to consider an image's appearance when choosing such things as shaders, color, and level of detail in modeling. Figure 2 shows an example of an image that can be displayed with several different kinds of rendering so students can understand their different visual effects.

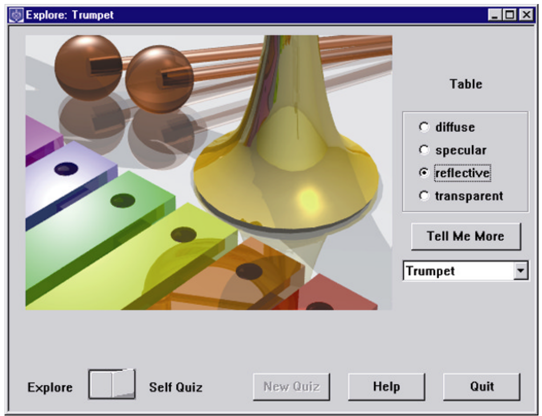

Figure 2: an example of an image that illustrates visual effects of algorithms

Many computer science programs will need to go beyond this first course in their undergraduate computer graphics offerings. There is a great deal of value in a two-semester sequence for undergraduate students wanting to develop a career in graphics, and further studies are needed to explore the possible topics and approaches for such a sequence. There seems to be a trend to begin with an API-based overview in the first semester and then treat topics in more depth in the second semester, often using pre-defined modules. Among the interesting ways this course could be organized would be to have students replace functions from the API with functions they wrote themselves based on fundamental algorithms. Another approach to advanced courses would be to include in-depth courses in human-computer interaction and in scientific visualization within the computer science program. In the context of advanced courses, computer graphics has a rich potential as a capstone course. It can draw together work from a variety of disciplines including computer science, mathematics, physics, perceptual and cognitive psychology, and software engineering. It can also serve as a source of collaboration with local industry.

The working group on computer graphics in computer science did not address any issues in graduate education in computer graphics, because such education is oriented towards research goals and focuses on the specialties of the individual instructors. It does not seem appropriate to try to make general statements about issues that depend so heavily on individual institutions' and instructors' specialties, interests, and resources.

Arts

The defining nature of technology in the arts is constant change, and arts programs should be flexible enough to adapt to new developments. Adding computer arts areas introduces issues in teaching, in support, in developing both expanded fundamentals and new courses in the overall curriculum, in interdisciplinary collaborations, and in assessment. In return the arts program will get new insights and opportunities for its students.

Computer arts allow a diversity of expression and educators are encouraged to determine whether a general or a specialized focus is appropriate within their courses and curricula. These curricula may encompass diverse topics that span various disciplines including computer science, film, music, and psychology. Educators are urged to build their curricula on several principles:

- course work in digital arts should focus on creative and technical concepts rather than just hardware and software,
- the overall curriculum should provide a historical and theoretical traditional art context for the development of computer arts and digital technology,
- students in the digital arts should begin the computer art core as soon as possible,
- a digital arts program should provide an environment that stresses problem solving skills and learning resourcefulness,
- students must be encouraged to develop both individual and group communication skills,
- the program should emphasize the fundamentals of visual language important to all artistic disciplines, including those that use the computer, and
- the overall foundations program in an arts curriculum should include digital concepts as well as an overview of the variety of expression possible with the computer in introductory computer art classes.

Educators are particularly urged to note the last point and encourage the introduction of digital visual concepts within art foundation education. This will allow students to work with concepts that are not generally accessible in arts courses, including the imaging and modeling needed for 2D and 3D still images, managing aspects of time for animation and video, and creating interactive experiences on CD or the Web. It will also allow arts programs to build interdisciplinary work within the arts as digital areas interact with areas such as photography or painting.

Figures 3 and 4 show examples of student art works based on very different media. Figure 3 is was created with Maya by a team of art and computing students who explored various effects that system offers, while Figure 4 is was created by a single art student using JavaScript as part of an interactive, Web-based work. Part of the work of Figure 3 was explicitly to explore the creation of shaders and to create images that expressed certain kinds of lighting, so this was not only an artistic but a technical effort. Figure 4, on the other hand, was intended to explore abstract and symbolic ideas in an interactive environment.

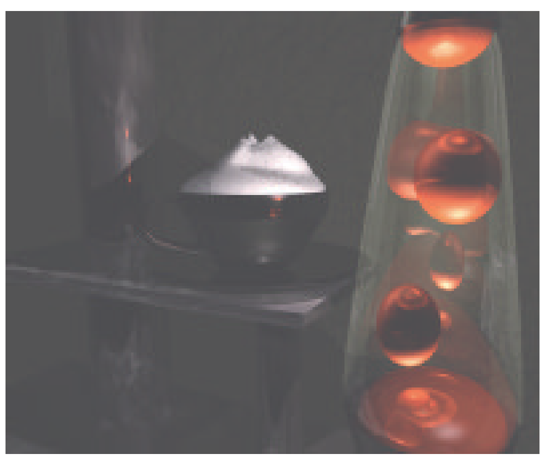

Figure 3: a lava lamp and cup of cappuccino

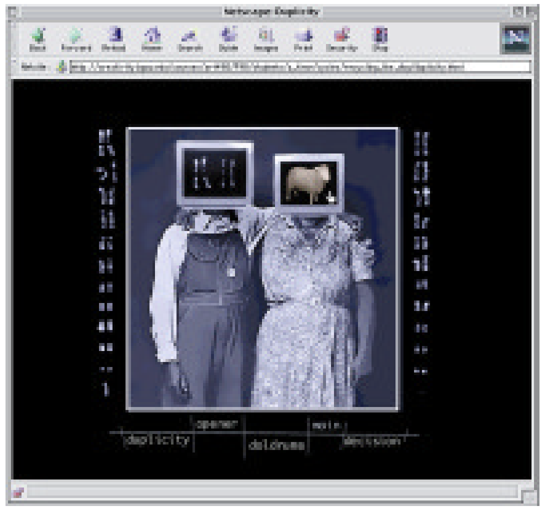

Figure 4: a Web-based art work

There are a number of other issues that continue to be very important in computer graphics instruction in the arts. These include creating adquate funding and technical support to deal with limited equipment and faculty resources, developing policies on the teaching workload that take appropriate account of the difference between the studio and the laboratory, answering questions of basic competency of incoming students, and developing objective assessment (both internal and external) of student work. Computer arts programs are strongly encouraged to foster environments that encourage dialog, collaboration, and common projects between departments, disciplines, cultures, and with industry. The fundamental principle from the working group on computer graphics education in the arts is simple: technologies will change, but good art fundamentals will not.

Media

Media consists of systems for the delivery of contents to users. The content to be delivered is usually in the arts, entertainment, or education. This field encompasses communication, dissemination of information, and cooperation among different subjects. Among media we would include 2D and 3D images, sound, and motion. Interactive media implies active participation by the user and implies feedback to reinforce the user’s action. The multiplicity of devices and standards used in the individual media, as well as the difficulty of combining materials from different media, have been a barrier to the creation and dissemination of media-based materials. However, the growth of computer-based techniques and technologies for media have led to software standards that can override hardware dependency.

The working group on media believe that new technologies, such as the Web, interactive television, and virtual environments, offer new frameworks for communication and broaden human communication channels. This field is a major client for computer graphics development and practice, and offers many kinds of professional opportunities for our students.

Perhaps the main issue in the use of media is design, which not only includes visual content design but also the design of the process and of tools for media production. The design criteria are often unique to each type of media and to the needs of the people working in the field. It is important that artists and technologists who work in the media field have a sound understanding of the existing graphics techniques for media, such as computer graphics, animation, and image processing, as well as possessing the basic skills for the creative usage of the media and the development of technology for them.

Computer Graphics for Teaching

This working group, with participants from many disciplines who teach at different levels, discussed challenges in using computer graphics for teaching. In creating courseware, there are problems in bridging the disciplines between the graphics specialist and the discipline for which teaching materials are being developed. In using courseware for teaching, problems included finding existing high-quality resources and in connecting with others doing similar work. Two examples of computer graphics developed for instruction are shown in Figures 5 and 6 below. Figure 5 is an image from a system that is intended to develop specific skills in students, while Figure 6 is from a system for teaching students about environmental issues. There is also typically less reward and recognition for creating and using computer graphics in teaching than for research, and it is very difficult to measure the effectiveness of these methods. This working group identified two specific topics of concern.

Figure 5: a street image for teaching students to drive

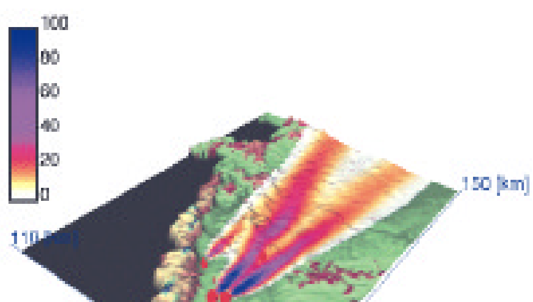

Figure 6: an image showing environmental pollution downwind from a power plant

Access to high-quality resources

To help educators find resources, SIGGRAPH and Eurographics should jointly support an extensive digital library of educational materials and resources. Resources would include materials from Eurographics and SIGGRAPH sources, from other organizations and conferences, and from general submissions from graphics educators. This library would serve as a portal through which computer graphics educators worldwide could find reviewed or refereed modules and other teaching materials, a collection of best practices in using computer graphics to teach in all disciplines, and a searchable, annotated, moderated list of URLs containing additional graphics-based teaching materials. This library is described in the diagram in Figure 7 below.

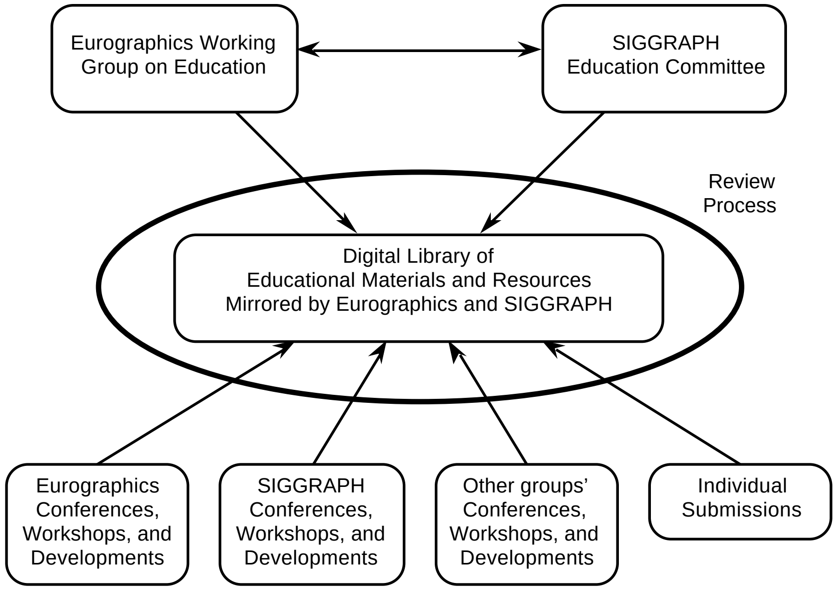

Figure 7: the structure of the computer graphics education portal

In order to ensure that the library would contain only the highest-quality resources, it should be promoted widely in the computer graphics community. Quality is one of the key concepts in making the library attractive to submitters and useable by instructors. There is an immediate need to develop a review process and a broad, multi-national review committee to review current materials and to evaluate materials as they are submitted in order to assure that all the content on the portal is of the highest quality. In the longer term there needs to be consideration of ways to identify and nurture materials needed to fill gaps in the content, to encourage the re-use of library materials, to develop feedback and user comments on materials, and to recognize particularly high-quality or high-value materials on the site. This library further needs to be linked into the growing collection of refereed teaching resources, not only in computer science but in all the disciplines that can use graphical tools and techniques in their work. The visualization tools and teaching resources make this especially important for the sciences.

In the long term, a refereed journal for articles on computer graphics and teaching is needed to put the credibility of teaching on the same level as research. A first step will be to compile a list of current journals having educational sections. Next, in order to show that there is both a supply of good material in the area and a demand for such a publication, a book will be developed, *Computer Graphics: Tools and Techniques for Teaching*, similar to the very popular series of *Graphics Gems* books. The contact person for this book project is Mike Bailey of the San Diego Supercomputer Center, `mjb@sdsc.edu`.

Improving our knowledge of distance and online education

A further concern of this working group was the entire issue of distance and online education. Clearly computer graphics is a key component of communicating ideas to students in all academic areas, but successful use of graphics here is linked to more general issues, and we have insufficient understanding of the real nature and opportunities of distance and online education.

The group acknowledges that online education is distinct from distance learning. For example, successful distance and online education seems to need a more motivated learner than traditional classroom education. The working group suggests that we need to have a better model of the learner and of how the learner acquires knowledge, and about how to help the learner interact effectively with content. Online education may be remote or it may be local, and it is largely characterized by a move from instructor-centered education to learner-centered education. An example of online education is given by the display in Figure 8. The working group sees a benefit in having courses move from being all face-to-face to being partly face-to-face and partly online. This frees up classroom resources and supports a broader set of student learning styles.

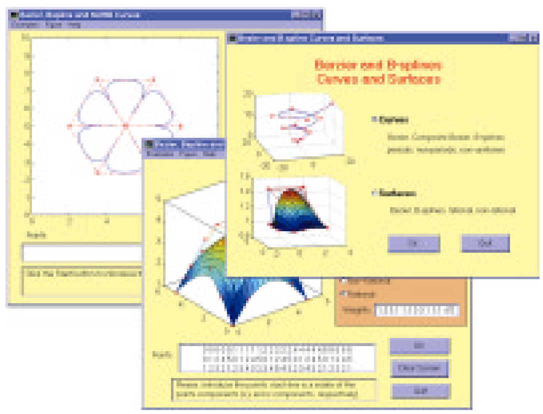

Figure 8: online presentation of computer graphics topics

The group was especially concerned about the lack of real understanding of distance learning, as well as the role of computer graphics and other image content in such learning. It strongly recommends a careful survey of ongoing research into the relative merits of different approaches to distance and online learning and assessment methods, and recommends that case studies of good practice and experience be included in that survey. This survey should have as its final goal the identification of promising lines of research for the use of visualization tools and techniques in online and distance education.

Developing courseware for distance and online education

Developing courseware is a major issue for distance and online education. Experience shows us that courseware development is complex and is strongly interdisciplinary, involving at least

- people who teach in the field and can provide content, presentation, and assessment information,
- artists or graphic designers who can ensure good visual communication of the content to the student,
- experts in interaction and media production to prepare appropriate interactive experience and to ensure that the materials work properly with students, and
- programmers to create the simulations or other active elements in the materials.

This is an expensive process that could take as much as 100 hours of development to prepare one hour of materials. The cost depends on the content, media, use of templates, and re-use of previous material. This is a complex effort that requires balancing media, standards, communication, and content, and takes an experienced team that carefully follows the latest developments in interactive technology. In addition, it is critical that the developing team develop and pay proper attention to quality certification and production management.

Interaction

The question of interaction ran throughout the topics above. Current graphics APIs and tools open opportunities for education in interaction. 3D navigation and selection enable understanding of complex visual data and are essential for multidimensional explorations. They provide the opportunity to allow users to experience a graphical world as an integrated, whole experience in which they have a measure of control. Unfortunately, the print medium for this report does not allow us to present any figures showing interactive work.

Interaction is clearly a critical issue in considering computer graphics for teaching. One of the primary values of good courseware is involving the student in exploring new subjects: for navigating in information spaces, for interactive simulations, and for shared environments. Choosing natural interaction techniques and providing appropriate student feedback using the range of senses available to the computer are keys in creating tools that engage and inform the student, and learning how to create effective interactive learning experiences is a key issue in developing the courseware suites needed for online and distance learning.

There is no short answer to the question of where and how students should learn about interaction. It has components in a number of disciplines and involves many modalities, and designing interaction requires knowledge of computer science, communication, design, perceptual and cognitive psychology, and ethics. Educational programs that teach interaction need to take a multidisciplinary approach that takes this complexity into account.

The working group considered the issue of interaction devices and tools, and noted that many people seem to be comfortable with current technologies, and they are reasonable for many applications. However, the ubiquitous WIMP (Windows, Icon, Mouse, Pointer) technology seems dated and does not permit techniques such as 6DoF (six degrees of freedom) devices to control motion in 3D space. The group believes that research is needed in interaction techniques and technologies, and encourages such research to open new doors for our users to interact in visual settings and to encourage the development of some research-level technologies into mass-market devices.

Collaboration

Another consistent theme in the workshop was collaborations in education. These can be simple collaborations between students in group projects, collaborations between disciplines at the same institution, collaborations between individuals or groups at different institutions, or collaborations between institutions and industry. Such collaborations raise a number of issues in supporting technology, in working across disciplinary cultures, in managing language, cultural, and time differences, but are seen as powerful tools to expand the breadth of a student’s experience. They also provide a mechanism for real-time feedback on the effectiveness of a curriculum and for curriculum development. The unique role of computer graphics in such collaborations is in either content or supporting technology, with important needs for development of networked graphics to take advantage of the possibility of shared environments.

The dimensions of collaboration are summarized in Table 1. Each row describes one dimension of a collaboration, and the two entries are the “extremes” of that dimension. For example, in the first row we consider the dimension of time, and we note that a collaboration can be synchronous (everyone works together at the same time) or asynchronous (everyone works at his or her own rate) — or the collaboration can have some aspect of each (for example, everyone works at his or her own rate, but there are points where everyone commits to completing one phase of a task and the work is synchronized before moving to the next phase).

Time:	Synchronous	Asynchronous
People:	Lecturers	Students
Discipline:	Within one	Among several
Distance:	Same place	Different place
Country:	Same country	Different country
Institutions:	Universities	University/industry

Table 1: the several dimensions of collaboration

Collaborations (multi-disciplinary, multi-cultural, or industrial) can lead to more effective international communication. These collaborations may include students working together, or teachers collaborating on a course, although they are geographically separated. They may also include internships for instructors in industry as a way for instructors to stay current. Collaborative courses may be interdisciplinary, or they may be within the same discipline with students in different locations. High-performance networks are essential in courses that include global student interaction. Students may communicate through simple teleconferencing, by sharing animations or complex graphical objects, or by entering "shared realities" to explore together in a networked, tele-immersive environment. The appropriate hardware and software are important, as are access to high-performance local, national, and international networks.

Several figures below illustrate collaborations of various sorts. Figure 9 is an image from an animation that was created by a collaboration between art and computer science students. Figure 10 is an architectural design that was created by a collaborative team to explore features of image generation. Figure 11 is from an interactive multi-site artistic shared reality. Figure 12 is from a two-site shared world to study an engineering problem. This breadth of collaboration illustrated by these figures only suggests the beginning of the value such collaborations can provide for education.

Figure 9: an image from an animation of chickens acting with autonomous behaviors

Figure 10: an architectural rendering

Figure 11: an image from a multi-site interactive experience

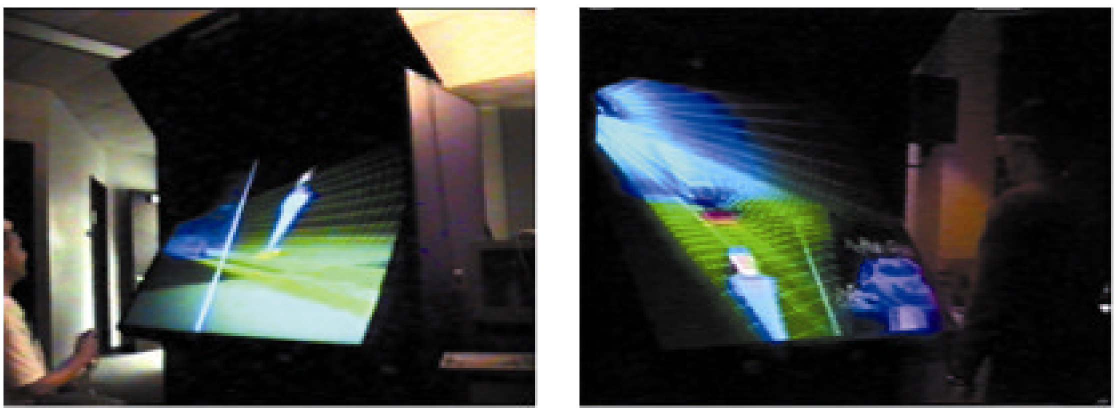

Figure 12: two images from an international collaboration on an engineering problem

Participants

Figure 13: workshop participants at the workshop hotel in Coimbra, Portugal

Vera Anand, Clemson University, USA
Dan Bailey, University of Maryland, Baltimore County, USA
Mike Bailey, San Diego Supercomputer Center,USA
Jack Bresenham, Winthrop College,USA
Ken Brodlie, University of Leeds, UK
Judith R. Brown, The University of Iowa, USA
Colleen Case, Schoolcraft College, USA
Giampolo Chiappini, Consiglio Nazionale delle Richierche, Italy
João Cunha, LNEC/Universidade de Lisboa, Portugal
Steve Cunningham, California State University, Stanislaus, USA
Danail Dochev, Bulgarian Academy of Science, Bulgaria
Dena E. Eber, Bowling Green State University, USA
David S. Ebert, University of Maryland, Baltimore County, USA
Laurent Fuchs, Université de Poitiers, France
Mário Rui Gomes, IST/INESC, Portugal
Werner Hansmann, Universität Hamburg, Germany

Thomas T. Hewett, Drexel University, USA
Lewis E. Hitchner, California Politechnic State University, San Luis Obispo, USA
Andres Iglesias, University of Cambria, Spain
Venkatesh Kamat, Goa University, India
Lars Kjelldahl, KTH, Sweden
J. Miguel Leitão, Instituto Superior de Engenharia do Porto, Portugal
Tony Longson, California State University, Los Angeles, USA
João Brisson Lopes, Instituto Superior Técnico, Portugal
Joaquim Madeira, Universidade de Coimbra, Portugal
Michael McGrath, Colorado School of Mines, USA
Bonnie Mitchell, Bowling Green State University, USA
Jacquelyn F. Morie, Rhythm and Hues Studios, USA
Anne Mumford, Loughborough University, UK
Mark Ollila, University of Gävle, Sweden
G. Scott Owen, Georgia State University, USA
César Páris, Centro de Computação Gráfica, Portugal
Radoslav Pavlov, Bulgarian Academy of Science, Bulgaria
Andres I. Prieto, University of Cantabria, Spain
Beatriz Sousa Santos, Universidade de Aviero, Portugal
Manuel Próspero dos Santos, Universidade Nova de Lisboa, Portugal
Pavel Slavik, Czech Technical University, Czech Republic
A. Augusto de Sousa, Universidade do Porto/INESC, Portugal
Henry Sowizral, Sun Microsystems, USA
José Carlos Teixeira, Universidade de Coimbra, Portugal
Akemi Tomida, University of Cantabria, Spain
Jorge F. Trinidade, IPG-ESTG, Portugal
Rosalee Wolfe, DePaul University, USA
Charles Wüthrich, Bauhaus-University of Weimar, Germany

Support

This work is supported by the National Science Foundation under award 9906124. All opinions, findings, conclusions, and recommendations in this work are those of the principal investigators, and do not necessarily reflect the views of the National Science Foundation. The workshop was also partially funded by ACM SIGGRAPH as part of its celebration of the 30th anniversary of the organization.

Image credits, by figure number in the text

1. Ben Eadington, California State University Stanislaus; an image from a student project on pseudo-fractal landscapes midway through an introductory computer graphics course in computer science. The project also includes interactive scene rotations and menu selections.
2. Rosalee Wolfe, DePaul University; an image from the TERA system for teaching about the visual effects of graphics algorithms.
3. Cappuccino by lava lamp light: Copyright 1999, Ava Collins, Alex Eller, Jason Lubawski, Marlin Rowley, Christian Valiente, University of Maryland, Baltimore County. Faculty Advisors: Dan Bailey and David Ebert.
4. “Recycle the Dog,” Mat Brandeberry, Bowling Green State University; an artistic WWW site which explores the concept of time.
5. J. Miguel Leitão, Instituto Superior de Engenharia do Porto; a modeled road used in a driving simulator
6. Pavel Slavik and Frantisek Hrdlicka, Czech Technical University; a simulation and visualization of pollutants distributed from a stack in a power plant as part of the education of power engineering students.

8 Andres Iglesias, University of Cambria; several screens from a Mathematica package for teaching CAGD and computer graphics

9 Autonomous Chicken Farm: Copyright 1999, Tracey Corder, Will Gee, Mike Keesey, Joe Romano, University of Maryland, Baltimore County. Faculty Advisors: Dan Bailey and David Ebert.

10 Mark Ollila, University of Gävle; design for a dental office by an interdisciplinary student team implementing lighting, reflection maps, and radiosity concepts using available tools.

11 Image of the Martian Landscape from Art World, courtesy of the Scientific Computing and Visualization Group at Boston University. The following artists contributed to the scene: Matt Harter, Paul Haman, Tom Coffin, Jeong-Hoon Lee, and Karlo Takki.

12 Two images from an international interactive shared reality between the University of Iowa and the National High Performance Computing Center of Taiwan to study a computational fluid dynamics problem in mechanical engineering

13 José Carlos Teixeira, University of Coimbra; photograph of workshop participants at the workshop hotel in Coimbra, Portugal.

* Author's current address:
San Diego Supercomputer Center
P.O. Box 85608
San Diego, CA 92186
rsc@sdsc.edu