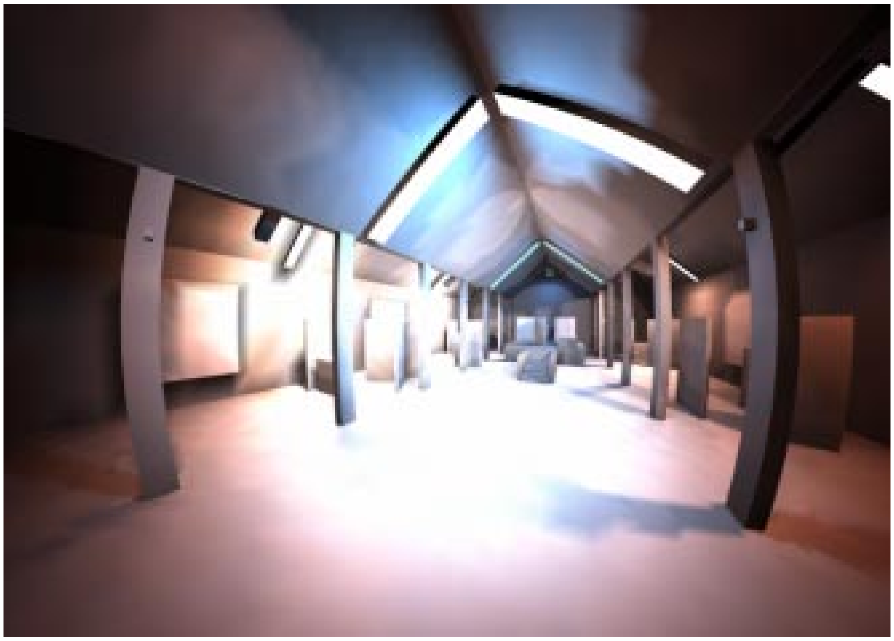
SIGGRAPH 2001 COURSE 15



Visualizing Relativity

Course Speakers

1. **Andrew J. Hanson**
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Abstract

This course is intended for attendees with simultaneous interests in the concepts of relativistic physics and in the practical extension of computer graphics methods to relativity. The first half of the course will focus on how relativistic effects can be intuitively understood starting from extremely simple Euclidean 2D geometry. The concept of object vertices as world-lines moving in a space that can be mixed with time is explained first in this context. Relativistic imaging is then explained in three dimensions, two space plus one time, exploiting analogies with Euclidean 3D geometry. Finally, four-dimensional spacetime is introduced to make the transition to the real world simulations treated in the final part of the course.

The second half will concentrate on recent advances in visualization and photorealistic simulation of relativistic scenes and phenomena using computer graphics to show features that could never be seen in real life at human time and space scales. Properties of light under the extreme conditions of both special and general relativity will be discussed, including changes of color, intensity, and direction of light, and gravitational light bending. A survey of state-of-the-art rendering techniques will be presented and selected animations produced using recently developed methods for relativistic rendering will be shown. An introduction to user interaction in special relativistic virtual environments will conclude the presentation.

Speaker Contact Information

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Speaker Biographies

Andrew J. Hanson is a professor of computer science at Indiana University, and has regularly taught courses in computer graphics, computer vision, and scientific visualization. He received a BA in chemistry and physics from Harvard College in 1966 and a PhD in theoretical physics from MIT in 1971. Before coming to Indiana University, he did research in theoretical physics at the Institute for Advanced Study, Stanford, and Berkeley, and then in computer vision at the SRI Artificial Intelligence Center in Menlo Park, CA. He has published in IEEE Computer, CG&A, TVCG, ACM Computing Surveys, and has over a dozen papers in the IEEE Visualization Proceedings. He has also contributed three articles to the Graphics Gems series dealing with user interfaces for rotations and with techniques of N-dimensional geometry. Previous experience with conference tutorials includes a Siggraph '98 tutorial on N-dimensional graphics, a Visualization '98 course on Clifford Algebras and Quaternions, and a tutorial on Visualizing Quaternions presented at both Siggraph '99 and Siggraph 2000. Major research interests include scientific visualization, machine vision, computer graphics, perception, and the design of interactive user interfaces for virtual reality and visualization applications. Particular visualization applications currently being studied include an astrophysical treatment of the local galactic neighborhood of the sun, the exploitation of constrained navigation for visualization environments, and applications of graphics in dimensions greater than three to mathematics and theoretical physics.

Daniel Weiskopf is researcher and teacher of computer science at the Visualization Group (led by Prof. Thomas Ertl) at the University of Stuttgart (Germany). He studied physics at the University of Tübingen (Germany), San Francisco State University, and the University of California at Berkeley. He received a Diplom (M.S.) in physics from the University of Tübingen in 1997 and a Ph.D. in theoretical astrophysics in 2001. Daniel Weiskopf authored several articles on special and general relativistic visualization. In addition to his research on relativistic visualization, he is interested in communicating complex physical concepts to the public via visualization: several of his films were featured at major European festivals of scientific animations and TV broadcasts; he is a scientific collaborator in a couple of film projects; his visualizations have been included in a number of popular-science publications. Major research interests include scientific visualization, virtual reality, interaction techniques, special and general relativity.

Course Schedule

1. **13:30–14:20 Introduction (Hanson)**
   (a) Motivation
   (b) 2D Euclidean vs Minkowski: Build Relativity concepts from 2D Graphics
   (c) Spacetime points and the twin paradox
   (d) Relativistic objects, cameras, and imaging
2. **14:20–15:00 Visualization Methods in 3D and 4D (Hanson)**
   (a) 3D = 2 Space + 1 Time: Transformations
   (b) Multiple transformations and Thomas Precession
   (c) Aberration of Light
   (d) Object Viewing: Occlusion, IBR, Terrell effect
   (e) 4D = 3 space + 1 time
3. **15:00–15:15 Break**
4. **15:15–15:40 Light (Weiskopf)**
   (a) Fundamentals (electromagnetic wave, photons, plenoptic function)
   (b) Relativistic effects on light (aberration, Doppler and searchlight effects, transformation of the plenoptic function)
   (c) General relativistic effects (bending light by gravity, gravitational lensing)
5. **15:40–16:30 Rendering (Weiskopf)**
   (a) Special relativistic rendering methods (polygon rendering radiosity, ray tracing, image-based rendering, texture-based rendering)
   (b) General relativistic rendering (ray tracing, image-based rendering)
6. **16:30–16:45 User Interaction (Weiskopf)**
   (a) Accelerated motion of observer in special relativity
   (b) Interactive virtual environment
7. **16:45–16:50 Conclusions (Weiskopf)**
8. **16:50–17:00 Questions and Answers (Hanson, Weiskopf)**

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