New Advances in
Computer Graphics

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New Advances in Computer Graphics

Proceedings of CG International '89

With 375 Figures Including 126 in Colour

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About the Cover:
The cover picture shows a scene from the computer animated movie, *The Great Train Rubbery*, Brian Wyvill designed the train made from an iso-surface in a scalar field. Brian Graham made the bridge from an old Canadian Pacific design, Jeff Allan bent the bridge using dynamic simulation techniques and Angus Davis wrote much of the rendering and support software.
The inside cover shows two scenes which demonstrate the results of an algorithm for generating knots and braids. Chengfu Yao developed a generalised cylinder algorithm and draped the rope over the table. Brian Wyvill generated the knot algorithm from some ideas by Larry Bates. Chris Bone and Dave Jevans wrote the ray tracer and selected the material's constants using the Hall Light model.

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Preface

This volume presents the proceedings of the 7th International Conference of the Computer Graphics Society, CG International '89, held at the University of Leeds, UK, June 27-30, 1989. Since 1982 this conference has continued to attract high-quality research papers in all aspects of computer graphics and its applications. Originally the conference was held in Japan (1982-1987), but in 1988 was held in Geneva, Switzerland. Future conferences are planned for Singapore in 1990, USA in 1991, Japan in 1992, and Canada in 1993.

Recent developments in computer graphics have concentrated on the following: greater sophistication of image generation techniques; advances in hardware and emphasis on the exploitation of parallelism, integration of robotics and AI techniques for animation, greater integration of CAD and CAM in CIM, use of powerful computer graphics techniques to represent complex physical processes (visualization), advances in computational geometry and in the representation and modelling of complex physical and mathematical objects, and improved tools and methods for HCI. These trends and advances are reflected in this present volume. A number of papers deal with important research aspects in many of these areas.

From the papers submitted to CG International '89, the International Program Committee selected 44 papers. These have been grouped together into 10 chapters as follows: Algorithms, Computational Geometry, Computer Animation, Computer Art, Theory and Graphics Interface, Hardware, Image Processing, Modelling and CAD, Ray Tracing, Rendering, and Applications. The latter chapter contains a number of contributions in the general area of applications. These were also selected from those submitted. One of the objectives here is to encourage and promote dialogue between computer graphics and its applications areas.

In addition to the reviewed submitted papers, there are also 4 invited papers and one keynote paper. These represent leading-edge research aspects in computer graphics and discuss issues pertinent to the continued advancement of the subject. Countries represented in this volume include USA, UK, Japan, Canada, Australia, People's Republic of China, Finland, Switzerland, Italy, France, Netherlands, and New Zealand. There is thus a wide international coverage.

It is being increasingly recognized that computer graphics is a tool for users and practitioners, not just researchers in computer graphics. This relationship with the real world of scientific investigation has two-way benefits. The application areas benefit by being able to use the latest methods and techniques, and even the latest hardware. In turn, computer graphics benefits by lessons learned in the general areas of useablity, HCI, application interfaces, and the metrics of performance. Visualization in science and engineering is one such area of keen interest: scientisits and engineers are realizing that computer graphics and animation is an important tool for research.

The fields of graphics and image processing are moving closer together through the important developments on the hardware front, and each are benefiting greatly from this mutual association. This volume brings together many of the leading key researchers in these fields. This symbiosis will be important for all those having a serious interest in evaluating current research work and profiling future developments and applications.

Thanks are expressed to the following cosponsors of the Conference: Computer Graphics Society, British Computer Society, University of Leeds, Japan Systems Company Ltd, Graphica Computer Corporation, and the University of Calgary. We are also grateful to all those who assisted with the reviewing of papers and the organization of the Conference. A list of the Committees of the Conference and the reviewers appears at the end of this volume.

R.A. Earnshaw
B. Wyvill

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Chapter 1
Invited and Keynote Papers

An Interactive Display for the 21st Century: Beyond the Desktop Metaphor

H. Fuchs

KEYWORDS: interactive three dimensional computer graphics, head-mounted display, 3D interaction, real-time graphics.

Vannevar Bush's 1945 vision of a personal desk-sized machine (the *memex*) containing a massive library of information and powerful search and recall mechanisms remains an inspired view of a useful personal computer. By 1970 Alan Kay at Xerox Palo Alto (California) Research Center was proposing a dynamic book-sized computer, a *dynabook*, that would satisfy most of the needs of users of all ages. By 1973 a group of his colleagues had built a small desk-sized computer, the Alto, that was starting to satisfy Kay's vision. By the mid-1980's the Apple Macintosh, and similar machines, were having the same effect on users worldwide. Common to all these visions was the computer interaction mechanism consisting of a 2D computer display that appeared like stylized version of the user's desktop: papers strewn about, ones on top obscuring ones below; various objects of interest, such as trash cans and clocks, serving their obvious and useful functions. The user moved objects about the screen and took them in and out of file folders by direct manipulation. In certain situations, the user could "zoom in" to certain papers for a closer look.

This is a fine model for 2D applications and is properly on its way toward universal adoption. Applying it to 3D applications is more troublesome: it is difficult to visualize 3D objects and scenes on a 2D screen and even more difficult to manipulate them. To understand the additional burden of 3D over 2D, consider the comprehension of a 3D design of a small house versus the comprehension of a 2D example of schematic layout -- current graphic workstation well adapted to the schematic layout, not well adapted for understanding the 3D spacial structure of the house. Just moving through the house, constantly changing viewing position and looking about would be very awkward. Modifying even a simple portion of the design, such as moving the location of a door, would indeed be difficult.

Sutherland's 1965 vision of the "ultimate display" and his 1968 demonstration of head-mounted display as the first approximation remain the most promising user devises for truly interactive 3D display of the 21st century. Unfortunately Sutherland's 1968 display was so far ahead of its time that little of the enabling technology was then (or even now is) available. A few researchers [Fisher 86] have been developing this vision, but most experts have relegated the head-mounted display to a mere paragraph in each textbook. The

military applications have been attractive enough, however, that there is sufficient long-standing interest to support a two-day conference ("Helmet-Mounted Displays", SPIE conference Number 1116, March 28-29, 1989, Orlando, Florida).
Several difficult problems need to be solved before a widely useful system can enlarge the user's computer space from the virtual desk to the virtual office. The image generation needs to be at least 30 frames per second and very likely 60 frames per second. The head gear needs to be reduced from its current helmet size to one that's closer to the size of a pair of clip-on sunglasses. The head-tracking should allow the user to roam within an office-sized environment without constraints.

Fortunately several new technologies based on microelectronics developments might provide solutions to the above problems. The solutions may be as far away as today's "walkman" is from crystal radios, so predictions of success are premature at best. Many would recommend that we abandon these systems for several decades to allow technology to develop. One can only hope that there are some developers who are not content to wait so passively.

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The author is grateful for a decade of discussions and work on head-mounted displays and related topics with colleagues Fred Brooks and Steve Pizer. Many graduate research assistants have worked on the project. Particularly appreciated are discussions in recent semesters with James Chung and Michael T. Kelley, and help in the last few weeks from Randy Brown.

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Biography

Henry Fuchs is Federico Gil professor of computer science and adjunct professor of radiation oncology at the University of North Carolina at Chapel Hill. He received a BA in Information and Computer Science from the University of California at Santa Cruz in 1970 and a PhD in computer science from the University of Utah in 1975. He has been an associate editor of *ACM Transactions on Graphics* (1983-1988) and the guest editor of its first issue. He was the technical program chair for ACM Siggraph'81 Conference, chairman of the 1985 Chapel Hill Conference on Advanced Research in VLSI, and chairman of the 1986 Chapel Hill Workshop on Interactive 3D Graphics. He serves on various advisory committees, including that of NSF's Division of Microelectronic Information Processing Systems and Stellar Computer's Technical Advisory Board.

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Cellular Self-Reproducing Automata As a Parallel Processing Model for Botanical Colony Growth Pattern Simulation

T.L. Kunii and Y. Takai

ABSTRACT

A cellular automaton is a model of natural systems composed of many identical components with local interactions. Particularly, self-reproduction property inherent in the cellular automaton is essential for modeling the biological and ecological growth pattern formation. In simulating such behaviour of cellular self-reproducing automata, interactive visual omputing allows us to get intuition from the model more easily and quickly. In this paper, we try to visualize the growth of a botanical colony based on Langton's two-dimensional self-reproducing cellular automaton. The colony consists of a reproducible fringe surrounding a growing core of empty shells. Realistic images of simulated life and death are shown vividly through an interactive visual simulation technique. We also discuss a parallel processing approach as an efficient method for high-speed visual simulation of large-scale cellular automata.

Keywords: cellular automata, self-reproduction, visual simulation, landscape design, parallel processing.

1. INTRODUCTION

A cellular automaton is a mathematical model of complex natural systems composed of a large number of identical components with limited local interactions. Particularly, self-reproductivity inherent in the cellular automaton is essential for modeling biological and ecological growth patterns generation. Cellular automata were originally conceived by John von Neumann as formal structures for modeling self-reproducing machines [Neumann 1966]. Research on cellular automata was very popular in the 1960's, however, it was considered almost disreputable by the 1970's.

A renaissance in cellular automaton research began a few years ago when interactive computer graphics techniques made it feasible to visualize the complex behaviour of cellular automata [Wolfram 1986]. Visual computing is straightforward and intuitive in simulating cellular self-reproducing automata. It can be said that the visual computing has established a new research area: "experimental mathematics" [Brown 1987].

Besides contribution to theoretical fields, the visual computation extended applications of cellular automata to include image generation of botanical specimens and, further, computer-aided natural landscape design. Visualization based on a geometric interpretation of L-system [Prusinkiewicz 1988] which can produce truly realistic plants images, however, seems still limited in essence, attacking only the surface structures of plants and not concerned with the internal principles of life to form shapes. Morphological approach is no longer sufficient. Consideration of cause and effect in a life cycle is indispensable to more realistic visualization of plants including environmental factors. Visualization based on cellular automata allows us to represent the developmental process of living organisms following a central dogma in biochemistry: "transcription and translation".

In this paper, we try to visualize the growth of a botanical colony based on Langton's 2-dimensional self-reproducing cellular automaton. Firstly, we will review Langton's automaton which gives necessary conditions of self-reproduction while satisfying the significant criteria of transcription and translation. Taking an environmental factor into consideration, we explain that the model is powerful enough to simulate botanical colony growth patterns. Secondly, realistic images of simulated life and death are shown through interactive visual simulation. The method used is based on a visualization technique composed of concrete and abstract steps. We also discuss a parallel processing approach as the efficient way to visually simulate the behaviour of large-scale cellular automata at a high speed.

2. SELF-REPRODUCTION IN CELLULAR AUTOMATA

Von Neumann's automaton

The study on cellular automata owes much to the pioneering work of von Neumann [Neumann 1966]. His approach to the problem of self-reproduction was mathematical. He could exhibit a universal Turing machine embedded in a two-dimensional cellular array using 29 states per cell and the 5-cell (left, right, top, bottom, and itself) neighbourhood.

In a formal manner, a two-dimensional cellular automaton is defined by a four-tuple:

$$(Z \times Z, Q, X, F)$$

where Z is a set of integers, Q is a finite set of states, X gives the shape of the neighbourhood, and F is a state transition function. An element of Z×Z is called a cell. Mapping from a set of cells to a set of states is referred to as the configuration of a cellular space. The state transition function F is defined over an n-Cartesian product of the state set Q:

$$F: Q^n \rightarrow Q.$$

On the other hand, a set of the neighbours is defined as an m-tuple of a two-dimensional vectors:

$$X = (z1, z2, ..., zm).$$

For example, von Neumann's 5-cell neighbourhood, which is very common in two-dimensional cellular automata, is represented as: