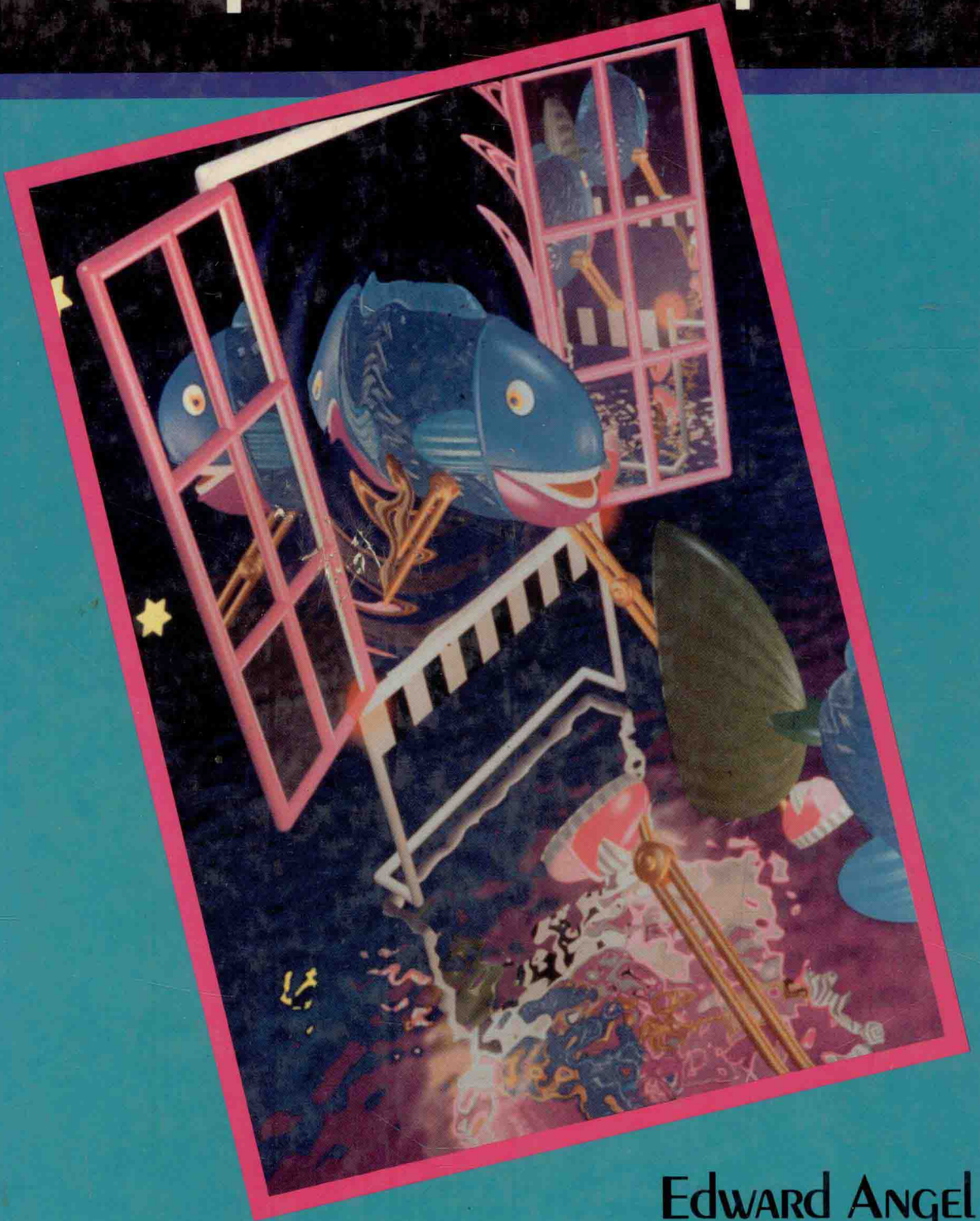


# COMPUTER GRAPHICS

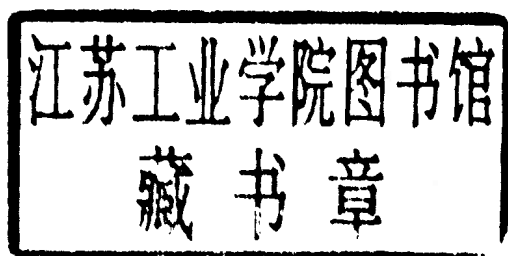


EDWARD ANGEL

# COMPUTER Graphics

**EDWARD ANGEL**

University of New Mexico



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■ **To Rose Mary**

# P R E F A C E

The past few years have seen a revolution in the way computer graphics is practiced. Computer graphics, while still an area of much activity in computer science, is also an area of great importance to students and practitioners of engineering, science, business, and mathematics. The advances in both hardware and software have led to the modern graphics workstation as a standard tool. These workstations include not only the hardware for high-resolution, bit-mapped displays but also the necessary software tools that allow users to develop their own applications. Thus, we are seeing the electrical engineer writing her own interface to a circuit-analysis package and mechanical engineers writing menu-driven CAD packages. For the computer scientist, computer graphics has expanded to include a wealth of new and exciting problems from the generation of photorealistic displays to the design of software tools.

This book is intended for use in a first course in computer graphics for computer scientists and engineers. Although such a course is normally taught for seniors, the only prerequisites assumed are good programming skills (equivalent to CS 2 in the ACM model curriculum) and trigonometry.

There are four fundamental precepts on which the book is based. First, with the availability of present software and hardware tools, it is both possible and important that students get working on significant *applications* of computer graphics early in the course. Hence, I have adopted a top-down approach that attempts to get students working on projects using Graphical Kernel System (GKS)—or any other available system—before we spend significant time on the standard graphics algorithms, such as line drawing and fill. This approach is in contrast to most books that use a bottom up approach that begins with pixels and works up through lines and eventually gets to applications.

Second, the adoption of GKS as the standard graphics language is of great significance to the teaching of computer graphics. In spite of its faults, GKS provides a conceptual basis for the teaching of computer graphics that is shared by many systems and allows us to teach using tools that can easily be transported to other systems. Just as we do not teach our own locally-developed programming language to our beginning students, I believe we should avoid teaching home-grown graphics software in a first graphics course.

Third, the increased programming skills of both engineers and computer scientists has had a significant effect on this book. Material such as modeling with hierarchical data structures, which most texts leave to the end or completely omit, is well within the abilities of sophomores and juniors in computer science and engineering. The chapters on transformations and hierarchical modeling are core to this book and appear early.

Finally, the expansion of our knowledge in computer graphics has made it likely that there will be at least two courses in computer graphics within most computer science departments. The first will be an introduction covering the range of the field with a significant emphasis on the systems and software engineering aspects of computer graphics. Follow-on courses will emphasize algorithms, geometric modeling, ray tracing, and computational geometry. This book is designed for such a first course.

The choice of the C language and the level of detail on GKS were decisions made after great thought and with the input of a number of people. C provides a nice balance between the desire to provide some abstraction while still being close enough to the machine that implementation issues can be discussed. The fact that it is presently the language of choice by implementors of graphics systems is an added benefit. The level of C used should not present any serious problems to students who know only Pascal or FORTRAN. The level of detail on the GKS C language binding may be more controversial. My experience with other books has been that a lot of class time has been wasted clarifying or correcting sketchy material on some particular graphics language used by the text. I have tried to strike a balance by using a subset of GKS but providing the details for the functions used. Even in courses that do not have an available GKS implementation, I believe it is important to see the details even if the students write no code. For those with other software systems such as PHIGS or some of the commercial systems, the changes necessary to convert the GKS code should be minor.

The first eight chapters form the basis of a one-semester senior course, primarily for computer scientists and computer engineers. The book can be used for a two-semester course by going into more depth on some of the algorithms and doing more than surveying the final two

chapters. For courses with a heavy project emphasis, a two-semester (or two quarter) sequence can be obtained by using Chapters 1–5 for the first course and Chapters 6–10 for the second. Chapters 1–4 and probably 5 should be studied in order. Chapters 6–7 and 8–10 are fairly independent of each other.

The book should also be accessible to professional programmers, engineers, computer scientists, and others. The notes that preceded this book are the basis for two four-day intensive short courses, one a survey of computer graphics and the other on GKS, which have been taught to thousands of programmers, engineers, and scientists in the United States and Europe.

I would like to acknowledge a number of people who have helped me not only with this book but also in learning computer graphics. This book started when I returned from sabbatical in 1982 to find there was no one available to teach computer graphics in my department. I thank the University of New Mexico for providing me with that opportunity and the facilities to develop a laboratory in computer graphics. David Collins, Eric Garen, and Anders Amundson of Learning Tree International, Inc. (formerly Integrated Computer Systems, Inc.) gave me the chance to create two short courses. Instructors, including Jim Burk, Mark Henderson, Mike Bailey, and Kelly Booth, and the thousands of participants in these courses provided significant feedback. Many students contributed to early versions of the programs and diagrams in this book. In particular, I wish to thank Mark McLaughlin, Dan Shawver, Mathew Nordhaus, and Joe Higgins. Of the many reviewers of various versions of the manuscript, George Grinstein, University of Lowell; Michael J. Zyda, Naval Postgraduate School; Lewis Hitchner, University of California, Santa Cruz; Spencer W. Thomas, The University of Michigan; Mark Henderson, Arizona State University; and Steve Wampler, Northern Arizona University provided particularly helpful comments. My colleagues John Brayer, Dick Nordhaus, and Bernard Moret were both knowledgeable and patient in filling in gaps in my knowledge in subjects as diverse as  $\text{\TeX}$ , data structures, and architecture (both computer and building design). Rab Hagy and George Schaeffer provided me with the latest versions of the GKS and PHIGS C language bindings at a crucial time. Professors Michael Duff of University College London and Mike Godfrey of Imperial College were extremely generous in providing me with friendship and facilities during my recently completed sabbatical leave.

A few comments on the illustrations in this book are appropriate. Early in this project, Jim DeWolf, of Addison-Wesley, and I agreed that a book on computer graphics should use computer graphics to generate all the figures and that all the figures must be of high quality. With the exception of the color plates, all diagrams were produced on

an Apple Macintosh SE by Rose Mary Molnar. Tools range from the use of Aldus Freehand (for most figures), to Super 3D, to the direct production of PostScript files from C programs. A few images, such as the pixel image of my cat Mongo, were created using a Thunder Scanner on an ImageWriter. Hopefully the figures are both informative and illustrate the quality of interactive graphics software presently available. Writing programs to generate the images in some of the figures or to create the kinds of drawing tools needed to produce such images can lead to innumerable interesting programming projects for students.

The people at Addison-Wesley, especially Karen Myer and Mona ZefTel, could not have been more helpful. I will have no author horror stories to share with my colleagues. A final thank you is due to Bob Drake. While Bob was at Addison-Wesley, he promised to (and did) call me once a month to convince me to do this book.

At this point, most authors thank their wives for their patience during the writing of their books. When your spouse is the illustrator of the book, patience is only one of many important and necessary characteristics. Fortunately for me, Rose Mary has so many wonderful qualities we were able to survive this experience.

Edward Angel  
University of New Mexico



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