SYMBOLIC COMPUTATION

G. Enderle K. Kansy G. Pfaff

Computer Graphics Programming

GKS – The Graphics Standard

Second, Revised and Enlarged Edition

Springer-Verlag

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With 100 Figures, Some in Color

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Dr. Günter Enderle†
Standard Elektrik Lorenz AG
Lorenzstraße 10, 7000 Stuttgart 40, FRG

Dr. Klaus Kansy
Gesellschaft für Mathematik und Datenverarbeitung
Schloss Birlinghoven, 5205 St. Augustin 1, FRG

Dr. Günther Pfaff
GTS-GRAL Graphische Standards für Computer-Systeme GmbH
Alsfelder Straße 7, 6100 Darmstadt, FRG

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In Memoriam Günter Enderle

Shortly before the second edition of this book went into print, we received the message that our friend and co-author of this book, Günter Enderle, died in a car accident on January 13, 1987, at the age of 42.

Günter Enderle received his Dipl.-Ing. (M.S.) in 1971 and Dr.-Ing. (Ph.D. in Engineering) in 1975 from the University of Karlsruhe. He was with the Karlsruhe Nuclear Research Centre from 1971 and became group leader for Computer Graphics and CAD. From 1984 onwards, he was responsible for software development at Standard Elektrik Lorenz (SEL) in Stuttgart. He was a member of EUROGRAPHICS from 1980. He held the position of editor-in-chief of the journal Computer Graphics Forum and inaugurated the book series Eurographic Seminars — Tutorials and Perspectives in Computer Graphics.

The Graphical Kernel System GKS was a focal point of his professional interests. He contributed significantly to its design as a member, from 1979, of the editorial board and by creative participation in the international review process. From 1981 he was chairman of the German Standardization Committee DIN-NI-5.9 (later renamed DIN-NI-21.2) "Computer Graphics" and head of the German delegation to the ISO Working group ISO/TC 97/SC 5/WG 2 (later renamed ISO/TC 97/SC 21/WG 2). Günter Enderle performed these tasks with great energy. He had the gift of motivating people participating in the different committees as volunteers to put all their force into the promotion of a common goal. Therefore, the success of the Graphical Kernel System GKS is closely related to his name.

For nearly ten years, the undersigned collaborated closely with Günter Enderle. For the second author (K.K.), this cooperation started 1978 within the Coordinating Committee "Computer Graphics" of the West German Association of National Research Centres (AGF) with the definition of the so-called AGF-Plotfile, a predecessor of the GKS Metafile.

All three authors came together through their membership of the GKS editorial board and had a very fruitful and productive time with the development of numerous versions of the GKS proposal and in dealing with the bulk of comments which came

in when GKS was presented to the international standardization bodies and which had to be handled before GKS was accepted as an ISO work item. In this task, Günter Enderle proved his ability in finding solutions for difficult problems and in realizing solutions within a short time.

The work around GKS included numerous meetings, national and international. These meetings were primarily devoted to hard technical work. Besides and through this technical work, "a network of deep friendship and common understanding has been established", as Günter Enderle himself expressed it on page 59 of this book. Therefore, we have not only lost a creative and dedicated colleague, but also a close friend, with whom we shared work and leisure time for many years. We are sure that our sorrow will be shared by all the colleagues who met Günter Enderle in the various German and international standardization committees for Computer Graphics.

Bonn, Darmstadt, February 1987

Klaus Kansy
Günther Pfaff

FOREWORD TO THE SECOND EDITION

When this book was published in 1983, the process of designing the Graphical Kernel System (GKS) was in its final stages. The final version of the first international standard for Computer Graphics was expected before the end of 1983. However, finalizing a standard is a complex and time-consuming process, so that the International Standard version of GKS appeared in August 1985. Before, the final letter ballot on GKS had been conducted. Comments raised in the ballot by the National Standardization Bodies have led to a number of small changes in the document. The final version of the GKS document was prepared in 1984 and forwarded to ISO central office for publication as an ISO standard. A number of GKS language bindings have also reached a stable and reliable status, and their ISO standard versions are expected soon.

Once GKS had been accepted and recognized as the cornerstone of a family of compatible graphics standards, a number of new projects were started with the aim of standardizing additional important graphics interfaces. The changes in GKS, the finalization of the GKS language bindings, the new projects in the computer graphics field, and last but not least, the extraordinary success of the first edition of this book, have led us to prepare this second edition.

The main differences from the first edition are as follows:

- All changes incorporated in GKS as a result of the final ISO letter ballot have been included.
- The language bindings, primarily FORTRAN and Pascal, have been updated to reflect the latest versions of the GKS Language Bindings Standard.
- The Pascal examples have been modified to reflect the traditional printed appearance of Pascal programs (e.g., keywords of the language are printed in bold letters).
- The three-dimensional (3D) extension of GKS has been completely revised. A new part (Part IV) presents in detail the proposed GKS-3D Standard which adds a complete set of 3D functions to GKS.

– The new projects on a Computer Graphics Metafile (CGM) and on Computer Graphics Interfaces for graphical devices (CGI) have been taken into consideration, where appropriate.

We are confident that this second edition will reinforce the original goal of this book, namely to offer a complete reference for understanding, using, learning, teaching, and implementing the Graphical Kernel System and its environment.

Karlsruhe, Bonn, Darmstadt, November 1986 *Günter Enderle*
Klaus Kansy
Günther Pfaff

FOREWORD TO THE FIRST EDITION

For several years the authors of this book have been involved in the design and the national and international review of the forthcoming graphical standard. When it became apparent that this process was coming to an end and the International Standard "Graphical Kernel System" (GKS) was cast into its final form, an urgent need arose to provide the graphics community with detailed information on the new standard, and to educate graphics programmers in GKS. One major goal of GKS, besides the portability of graphical application programs and device independence, is "programmer portability" which it aims to achieve by establishing a common basis for the training of graphics programmers. Having taken part in the development of GKS from the very early stages of defining the basic concepts and designing its first versions up to the final draft of the International Standard, we felt it would be worthwhile embarking on the venture of writing a text book on computer graphics programming based on GKS.

This book is aimed, on the one hand, at graphics users, experts and managers who want to gain an overview of the new standard and a better understanding of its concepts. On the other hand, it addresses graphics programmers who want to use GKS for realizing their graphical applications. It can serve as a basis for teaching and studying the functions, concepts and methods of GKS. Additionally, it will be a valuable source of information for implementors of GKS.

One of the main areas of application of computer graphics is Computer Aided Design (CAD). GKS can serve as an excellent base upon which portable CAD systems can be built. A thorough introduction to CAD is presented in another book in the SYMBOLIC COMPUTATION series: "CAD — Fundamentals and System Architectures", by J. Encarnação and E.G. Schlechtendahl [ENCA 82a].

The standard document defining GKS has to be complete and consistent, it uses formal descriptions where possible, and it has to adhere to certain formal rules for the specification of the standard. Only rarely does it give informal introductions, examples, or explanations for the decisions taken. For an over-

view such as this book aims to provide, however, an informal and less complete presentation is more suitable and examples, figures and explanations are essential for teaching purposes. We want to offer easy access to GKS and to the graphics environment in which it is situated.

It is of course inevitable in a book describing a standard that some material from the standard document will be used. The authors were members of the editorial team which designed GKS up to version 4.8 [DIN 79], and since then have taken part in the development of further versions of the GKS document up to the GKS standard. However, the GKS document is the result of combined contributions from many different people. We feel that the quality of the document is very high, and that there is no better way of describing some aspects of the GKS standard. Accordingly, in such cases the relevant parts of the document are reproduced in this book with little or no alteration.

The book is divided into five main parts. In Part I, an overview of the integration of GKS into the Computer Graphics framework is given and the principles and basic concepts of GKS are introduced and explained. Part II describes the design process of GKS in the committee NI/UA-5.9 of the Deutsches Institut für Normung (DIN), and the extensive international review and refinement carried out by the experts of working group TC97/SC5/WG2 of the International Organization for Standardization (ISO). The groups participating in this process, important events, and major design decisions, are presented, as well as the methods used for handling the review and the revision of the standard draft and for resolving conflicts.

Part III of the book is devoted to explaining the GKS functions and their applications. All GKS functions and their parameters are described, both in the language-independent form presented in the standard document and in the FORTRAN subroutine version. Various examples are given in the programming languages FORTRAN and Pascal. Exercises are provided in order to deepen the reader's understanding of the functions and to assist in the teaching of Computer Graphics programming on the basis of GKS. In Part IV, the 3D extensions to GKS are described.

The last part of the book covers the various interfaces of the standard within the Computer Graphics environment. Before a standardized graphics system can be used, it has to be implemented on existing hardware and operating systems. It is of course desirable that such implementations be validated and that their conformity to the standard be certified. The implementation of the standard in a given programming language is made possible by adapting the standard functions to the rules of that language. We describe the FORTRAN binding of GKS. Further interfaces

exist with graphical input and output devices, and with graphics metafiles for storage of pictures. Communication between members of the graphics community is facilitated by a common graphics terminology developed in parallel with the GKS standard.

Newcomers to the Computer Graphics field and readers who want an overview of GKS concepts should read Part I and then use the table of contents or the index at the end of the book to find information of special interest to them. Part II addresses itself to those interested in standards and how they are created. Programmers and scientists designing graphics applications will find a detailed description of the GKS functions in Part III. This part will also be the main reference for learning Computer Graphics programming on the basis of GKS. Part V will be of special importance to GKS implementors.

We hope this book will help to disseminate the application of the Graphical Kernel System, to explain its principles and concepts, and to promote Computer Graphics education on the basis of the first standard in Computer Graphics.

Karlsruhe, Bonn, Darmstadt, July 1983

Günter Enderle
Klaus Kansy
Günther Pfaff

DEDICATION

The subject of this book — the Graphical Kernel System — was developed in a long process starting in 1976 and has finally evolved as an International Standard. This book is dedicated to the graphics experts who designed GKS under the auspices of the Deutsches Institut für Normung (DIN), and who played a part in its evolution through the international review process within the working group TC97/SC5/WG2 "Computer Graphics" of the International Organization for Standardization (ISO) and various national standardization organizations. Over 100 scientists from all over the world invested more than 50 man-years in this venture, making GKS the consistent and complete graphics standard it is today, developing a concise terminology for Computer Graphics, establishing the firm basis of a methodology for Computer Graphics, and cooperating in a spirit of mutual confidence and friendship.

Members and experts of DIN-NI/UA-5.9 "Computer Graphics" 1975—1982:

R. Anderl, E. Bauböck, H. Borik, H.-G. Borutka, L. Brandenburger, H. Brüggemann, P. Dobrowolski, R. Eckert, P. Egloff, J. Encarnação, G. Enderle, B. Fink, H. Flegel, R. Gnatz, M. Gonauser, H. Grauer, I. Grieger, Th. Johannsen, E. Jungmann, K. Kansy, R. Karg, W. Klingenberg, R. Konkart, H. Kuhlmann, G. Lang-Lendorff, St. Lewandowski, G. Mittelstraß, G. Nees, H. Nowacki, D. Otto, K. Pasemann, G. Pfaff, F.-J. Prester, K. Reumann, J. Rix, H.-J. Rosenberg, F.-K. Roth, E.G. Schlechtendahl, J. Schönhut, R. Schuster, D. Stroh, D. Völkel, J. Weiss, J. Weskott, H. Wetzel, P. Wißkirchen.

Members and experts of ISO TC97/SC5/WG2 "Computer Graphics" 1977—1982:

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