An Introduction to the SCD Graphics System

Author: Gregory R. McArthur
Contributor: Lofton R. Henderson

SCIENTIFIC COMPUTING DIVISION
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
BOULDER, COLORADO
PREFACE

This document represents the first in a series of manuals which collectively describe the Scientific Computing Division (SCD) Graphics System. Each manual in the series has been designed to provide users with complete and accurate information on how to use the SCD Graphics System. The authors and contributors to this series of documents hope that you will find the information helpful and that you will be able to make maximum use of the Graphics System for your own purposes.

ACKNOWLEDGMENTS

Many individuals, too numerous to mention in this brief space, have given unstintingly of their time and expertise in the production of this document. Special thanks must go to members of the Graphics Project at NCAR who provided the author with invaluable assistance in understanding the scope and complexity of the SCD Graphics System. In particular, Fred Clare and Lofton Henderson provided timely and constructive criticism which contributed to the coherency and accuracy of this document. Ann Cowley, Ben Domenico, Barb Ostermann, and Linda Besen read many preliminary versions of the manuscript, catching ubiquitous typographical errors and omissions. Lofton Henderson provided the substantive content for Chapter 2: "A Brief Graphics User's Guide". While every effort has been made to ensure that this manual is accurate, any errors must be attributed to the author.
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CHAPTER 1: THE SCD GRAPHICS SYSTEM DOCUMENTATION

ORGANIZATION

The Scientific Computing Division (SCD) Graphics System documentation is organized into a series of separate documents. Each document is designed to be independent of the others. Hence, the suite of documents which comprise the SCD Graphics System documentation may be used by a wide variety of users with varying degrees of familiarity with graphics systems.

In general, users with no prior experience with graphics systems are encouraged to read through this introductory material before proceeding directly to the other documents. A short description of each of the SCD Graphics System documents follows.

An Introduction to the SCD Graphics System should be read by all users since it explains much of the philosophical and conceptual orientation of the Graphics System.

The SCD Graphics Utilities contains a detailed set of explanations for each of the higher-level graphics routines which are currently part of SCD's Graphics System. First time users should refer to the brief section at the beginning of this document in order to determine which graphics utilities will perform a desired task.

Selected User Reference Papers is a collection of papers which deal in detail with selected special applications of the Graphics System.

The System Plot Package documents the graphics routines which are used to perform low-level graphics tasks such as scaling, line drawing, and character drawing. Since most of the higher-level graphics utilities use the System Plot Package, users should be familiar with its overall features and capabilities before using the utilities.

The Graphics System Implementor's Guide tells the user how to implement various components of the Graphics System on their own computer or any target computer. This document is recommended for those users of graphics systems who wish to transport the SCD Graphics System to other computers and graphics devices.

TERMINOLOGY

Whenever possible the use of jargon or technically narrow terms has been avoided in this manual. However, the complete elimination of specific terminology germane to graphics systems is not desirable and, wherever such terms are used, they have been defined in context.
Each of the graphics utilities is a higher-level routine or package of routines for solving a relatively complex graphics problem. Use of the utility packages is encouraged over other methods of graphics production because high quality results may be obtained with a relatively small effort. Users who require only basic or low-level graphics capabilities should refer to The System Plot Package. Programmers wishing to transport, maintain, or expand the graphics software may wish to read the documentation covered in The Graphics System Implementor's Guide, The System Plot Package, and the Selected User Reference Papers.

While the Graphics Project at NCAR does not provide implementation support for distributed versions of the software described in these documents, they are interested in promoting the use and capabilities of the Graphics System and in improving its quality. Users with helpful feedback or who discover unexpected, undocumented problems are encouraged to contact the Graphics Project by forwarding this information to the NCAR Scientific Computing Division Consulting Office (303-494-5151 extension 579).
The National Center for Atmospheric Research (NCAR) provides a wide variety of resources to support and promote fundamental research in the atmospheric sciences.

The studies carried out by the diverse atmospheric sciences disciplines using NCAR resources typically involve modeling of atmospheric, oceanographic, and solar phenomena. To assist in these investigations, NCAR provides considerable computing power on its CRAY-1 and Control Data computers as well as significant peripheral services. The Graphics Utilities developed at the Scientific Computing Division (SCD) constitute an essential component of these peripheral services since coping with the enormous quantities of data associated with large-scale atmospheric modeling and data collection makes computer-driven graphics a necessity.

Recognizing this need, the Graphics Project at NCAR has developed a suite of graphics routines which maximize not only the resident capabilities of NCAR's computing hardware and graphics devices, but also permit quick and painless switching to other output devices at remote locations. Portability of the routines to computers at the home institutions of visiting scientists makes it easy for them to transport their programs home with them, thereby enhancing the overall value of the routines to the user.

Two design features of the SCD Graphics System have proved to be most valuable in its adaptation to different computing hardware and software environments. First, the routines are device independent. When application programs that use the system are designed, no prior knowledge of which device will display the results is needed. Second, the routines are highly portable. The Graphics System is easily installed on new computers and provides an unchanging user interface from one machine to another.

The Graphics System as a whole achieves device independence by generating metacode, a device independent plotter instruction code. The structure of metacode is simple and it can easily be translated to drive a wide range of devices. In essence, the user executes a program on some computer on which the Graphics System is installed and generates a metacode file. Then, either locally or remotely, immediately or at some later time, a postprocessor is run that translates the metacode file into the instruction set of some intended target graphics device. The Graphics System Implementor's Guide explains...
in greater detail how to write a metacode translator to add a graphics device to the user's system.

Portability

The SCD Graphics System is portable in the sense that the code comprising the system can be transported to a wide range of computing environments. Its portability is primarily the result of three design factors:

1. The system's language is FORTRAN; with rare exceptions the software is restricted to a subset of ANSI 66 standard FORTRAN.

2. The code for machine-dependent, inherently non-standard functions is strictly localized in a set of 14 "primitive services" routines.

3. The hierarchical, modular structure of the routines isolates potential trouble spots and reduces the possibility of the whole system being crippled by some local error.

Users are encouraged to read the Selected User Reference Papers document and the The Graphics System Implementor's Guide for a complete description of how to realize maximum portability for the Graphics System in their own computing environments.

Functional Characteristics

The SCD Graphics System is a data representation system. Its functions are heavily oriented toward organizing large amounts of numerical data and producing concise visual representations of these data. Its capabilities are best suited for the representation of scientific and technical data which include, but are not limited to, annotated graphs and scatter diagrams, a number of different techniques for presenting two and three-dimensional data fields, and generating high quality text fonts suitable for annotation of publishable technical figures. The Graphics System is less well suited for bar charts, pie diagrams, and commercial quality text fonts.

The system is primarily passive. Following directions from a user application program (which may be interactive), the system adds elements to the picture under development but does not allow the sort of intense user interaction with the picture that is typical of some other graphics systems. Thus the elements of the picture cannot be altered after they have been created.

Finally, the system is best characterized as a vector graphics system. It can drive almost any plotter or plotter-like device to produce line drawings as contrasted with television-like images of raster oriented systems.
Capabilities

At the simplest level, the user has direct access to routines for plotting points, lines, curves, characters, and for generation of basic backgrounds. Higher level capabilities are also available. Specific capabilities of each higher-level graphics routine will be found in The SCD Graphics Utilities, while lower-level routines are described in The System Plot Package.

The display of one, two, and three-dimensional data is handled in a number of ways, each dependent upon the user-desired output. For display of one-dimensional data, the system has a powerful automatic graphing package generating, among other things, sophisticated annotated backgrounds, multiple labeled curves per graph, and multiple labeled graphs per picture. Enhanced user control for displaying one-dimensional data is achieved by using the software dashed-line family of graphics routines. These routines permit up to four different image quality levels, ranging from simple dashed lines to spline-smoothed dashed lines with labels inserted and crowded lines removed.

Two-dimensional data fields may be displayed in a variety of ways, such as contouring of gridded and/or arbitrarily scattered data, half-tone representations of data fields, and generation of vector fields or streamlines. The user can even produce three-dimensional perspective representations of two-dimensional data fields which are proper mathematical functions of two variables.

Three-dimensional perspective representation of annotated graphs, curves in space, points in space, etc., is also provided. Iso-valued surfaces of functions of three variables can be displayed in proper perspective with hidden parts eliminated. Both high and low resolution of three-dimensional data fields are available. The family of three-dimensional graphics display utilities also includes a lettering routine which can write in any orientation for any one of the three orthogonal planes.

Additionally, there is a package for map representation of any section of the Earth in any one of the standard map projections (e.g. Lambert equal area, Lambert conformal conic, azimuthal equidistant, etc.). Facilities also exist for generation of characters and symbols in a range of qualities and for aiding movie production by generating scrolled titles.

Limitations

The limitations of the Graphics System are generally the result of its having evolved directly from a package originally designed to be executed on the Control Data 7600 series mainframes and to drive NCAR's dd80 device. In general, the Graphics System is much easier to port than
it is to produce from scratch. The System Plot Package is highly portable, as are most of the popular and heavily used graphics routines. Continuing refinement of all components of the system to be functionally portable is an on-going commitment of the Graphics Project at NCAR.

Users should note that some of the less frequently used routines are not as portable as might be desired. A few of the primitive support routines may be idiosyncratic with respect to some user host machines. Such problems, however, rarely prove to be fatal; they are more annoying than anything else. Readers are directed to look at each of the narratives for the individual graphics utilities for a full description of their portability.
CHAPTER 3: FUNCTIONAL CAPABILITIES OF THE SCD GRAPHICS SYSTEM

GENERAL CAPABILITIES

The SCD Graphics System has been developed to provide a wide range of graphics capabilities to scientists and researchers requiring graphical display of numerical data.

The higher-level graphics utilities in the SCD Graphics System are described in *The SCD Graphics Utilities*. Users may select from these utilities those capabilities which meet their individual graphics needs. The general capabilities offered by the graphics utilities range from simple contouring, labeling, and smoothing of lines through to vector and velocity fields, three-dimensional representations of data, half-tone shading, and map representation of any section of the Earth.

Each graphics utility may be thought of as a member of a family of utilities; each member performing a specific variation on a general graphic theme. Alternatively, users may wish to think of the capabilities of the graphics utilities in terms of the dimensionality of their own data (i.e. one, two, or three-dimensional data fields). Depending upon the user's orientation, both generalized schemes are presented below.

THE FAMILIES OF GRAPHICS UTILITIES

The graphics utilities have been grouped into seven families; each family performs a different function. Some of the graphics utilities require the support of other graphics utilities which may be members of different families. This is the case for contouring and automatic graphing. Users should refer to the detailed documentation for each utility in *The SCD Graphics Utilities* for multiple-utility use information.
Contour Plotting Family

This family of graphics utilities performs a variety of useful functions. Depending upon the type of data the user has (i.e. regularly or irregularly distributed data), the various utilities will generate contours and optionally smooth or label lines. The utilities beginning with the root CONREC operate on regularly distributed (gridded) data within a two-dimensional array. Those utilities beginning with the root CONRA are used for irregularly distributed (non-gridded) data within a two-dimensional array. The members of the family are:

**CONREC**
The standard contouring and labeling utility. It contours two-dimensional arrays, labeling the contour lines.

**CONREQCK**
Like CONREC but faster and smaller because the contours are unlabeled and software dashed-line support is omitted.

**CONRECSMTH**
Similar to CONREC, but bigger and slower because contours are smoothed as well as labeled.

**CONRECSUPR**
Similar to CONREC, but bigger and slower because contours are smoothed, labeled, and crowded lines are removed. This utility runs only on the CDC 7600.

**CONRAN**
The standard contouring and labeling utility for irregularly distributed data. It plots contours and smooths them using splines under tension.

**CONRAS**
Like CONRAN only bigger and slower because contour lines are labeled and crowded lines are removed. It may be used to produce publication quality maps.

**CONRAQ**
Similar to CONRAN, only faster and smaller because the data is triangulated and contoured. It is best for testing input data.

Note: The software dashed line capabilities of the DASH-CHAR family (see below) are required to support ALL contour plotting utilities except for CONRECQCK.
Dashed Line Family

This family of graphics utilities consists of software dashed-line packages with labeling and smoothing capabilities. In addition, crowded lines may be removed. The four utilities within the family are:

DASHCHAR

The standard dashed-line package with labeling capability.

DASHLINE

Similar to DASHCHAR, but smaller and faster because it has no labeling capability.

DASHSMTH

Like DASHCHAR, but bigger and slower because lines are smoothed.

DASHSUPR

Similar to DASHCHAR, but bigger and slower because lines are smoothed and crowded lines are removed.

Demonstration Plot for DASHSMTH

IPAT=DADADADADADADAD. K=1

IPAT=DDDDDDADADDDDD. K=2

IPAT=DDDDADDDADDDDD. K=3

IPAT=DDDDAAAAADDDDD. K=4

IPAT=DDDDDDDDADDDDD. K=5

In IPAT strings, A and D should be interpreted as apostrophe and dollar sign.
This family of utilities generates three-dimensional images. They may be used to generate iso-valued surfaces with hidden parts removed, display two-dimensional arrays in three-space, or to draw three-space lines. The members of the family are:

- **ISOSRF**: Displays iso-valued surfaces with hidden parts removed from a three-dimensional array.
- **ISOSRFHR**: Similar to ISOSRF except that the iso-valued surfaces are generated from a high resolution three-dimensional array. Hidden parts are also removed.
- **SRFACE**: Three-dimensional display of a surface (with hidden parts removed) from a two-dimensional array.
- **THREED**: Provides three-space line drawing capabilities with entry points equivalent to the line drawing entry points of the System Plot Package.

DEMONSTRATION PLOT FOR ISOSRFHR
The utilities in this family generate software characters in a variety of qualities. The members of the family are:

- **PWRITX**: Generates high quality software characters.
- **PWRITY**: Generates the simplest software characters.
- **PWRZI**: A character plotting utility used for plotting characters in three-space when used in conjunction with ISOSRF.
- **PWRZS**: A character plotting utility used for plotting characters in three-space when used in conjunction with SRFACE.
- **PWRZT**: A character plotting utility used for plotting characters in three-space when used in conjunction with THREED.

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The character set includes uppercase and lowercase letters, symbols, and other characters.
Vector/Streamline Family

This family of utilities provides users with the capability to plot representations of vector field flows using streamlines, or velocity fields using vector arrows with specified direction and magnitude. The members of the family are:

STRMLN Plots a streamline representation of two-dimensional flow fields displayed by drawing continuous streamlines with arrowheads indicating flow direction.

VELVCT Two-dimensional flow fields displayed by drawing vectors anchored at the data points.

DEMONSTRATION PLOT FOR ENTRY EZVEC OF VELVCT
Automatic Graphing Family

This family consists of only one utility:

**AUTOGRAPH**

Draws and annotates curves or families of curves. It requires the support of DASHCHAR.

DEMONSTRATING EZMY ENTRY OF AUTOGRAPH
The OTRAS Family

This family of utilities provides users with several programs which may be used to generate maps, to generate half-tone maps, to create movie titles, and to generate windowed or clipped pictures. The members of the family are:

EZMAP  Plots continental, political, and/or U.S. state outlines according to one of nine projections. Similar to SUPMAP, but runs only on the CRAY-1 mainframe.

HAFTON  Creates half-tone pictures from a two-dimensional array.

SCROLL  A movie titling package.

SUPMAP  Generates continental outlines and political boundaries under various map projections. Runs only on the CDC 7600 mainframe.

WINDOW  Provides a clipping capability for lines extending outside a user-defined window, thereby allowing part of a picture to be plotted without distortion or overwriting near the edge of the picture.

SUPMAP DEMONSTRATION: CYLINDRICAL EQUIDISTANT PROJECTION
Another way to view the capabilities of the SCD Graphics System is to consider the ways the graphics utilities handle dimensionality of the users data. Users who have one, two, or three-dimensional data arrays may wish to use this section to identify those routines which work best for the dimensionality of their data.

Users who wish to represent one-dimensional data fields should reference the Graphics Utilties documentation for the following utilities:

- AUTOGRAPH
- DASHCHAR
- DASHLINE
- DASHSMTH
- DASHSUPR

The Graphics System has a powerful automatic graphing package (AUTOGRAPH) which can produce sophisticated annotated backgrounds, multiple labeled curves/graph, and multiple labeled graphs/picture. One-dimensional data may be displayed under more direct user control with the family of dashed line graphics utilities.

Two-dimensional data fields can be displayed in a number of ways. The below listed utilities perform a variety of graphic representations of such data fields:

- CONREC
- CONRAN
- HAFTON
- CONRECQCK
- CONRAS
- SRFACE
- CONRECSMTH
- CONRAQ
- STRMLN
- CONRECSUPR
- VELVCT

Users with two-dimensional data fields should refer to the Graphics Utilities documentation for information on each of these utilities.

Perspective representation of three-dimensional annotated graphs, curves in space, points in space, etc., can be accomplished via the following graphics utilities:

- ISOSFR
- ISOSRFHR
- THREED

The utilities listed above can be used with a lettering utility which can write in any orientation on any one of the three orthogonal planes.
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