US Army Corps of Engineers
Construction Engineering Research Laboratory

AD-A252 461

USACERL ADP Report N-89/14
September 1989

2

GRASS 3.0 Programmer's Manual

by
Michael Shapiro
James Westervelt
Dave Gerdes
Michael Higgins
Marjorie Larson

This manual introduces the reader to the Geographic Resources Analysis Support System from the programming perspective. Design theory, system support libraries, systems maintenance, and system enhancement are all presented.

92 [illegible]

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE September 1989	3. REPORT TYPE AND DATES COVERED Final

4. TITLE AND SUBTITLE GRASS 3.0 Programmer's Manual	5. FUNDING NUMBERS WU A896-NN-TS9 WU A896-NN-TF9 WU A896-NN-TJ9 WU RD8P69NVC8
6. AUTHOR(S) Michael Shapiro, James Westervelt, Dave Gerdes, Michael Higgins, and Marjorie Larson	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Construction Engineering Research Laboratory (USACERL) PO Box 9005 Champaign, IL 61826-9005	8. PERFORMING ORGANIZATION REPORT NUMBER ADP N-89/14
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Engineering and Housing Support Center ATTN: CEHSC-FN Kingman Building Fort Belvoir, VA 22060-5580 USDA-Soil Conservation Service Cartographic and Geographic Information Systems Division 14th & Independence Avenue SW Washington, DC 20013	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This manual introduces the reader to the Geographic Resources Analysis Support System from the programming perspective. Design theory, system support libraries, systems maintenance, and system enhancement are all presented.

14. SUBJECT TERMS GRASS geographic information system Geographic Resources Analysis Support System	15. NUMBER OF PAGES 290 16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT SAR

Notice to Program Recipients

This program is furnished by the U.S. Government and is accepted and used by the recipient with the express understanding that the Government makes no warranty, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof.

The program belongs to the Government. Therefore, the recipient further agrees not to assert any proprietary rights therein or to represent this program to anyone as other than a Government program. The recipient also agrees that the program and all documents related thereto, including all copies and versions (except when expressly authorized otherwise) in possession thereof, will be discontinued from use or destroyed upon request by the Government.

The program is to be used only in the public interest and/or the advancement of science and will not be used by the recipient to gain unfair advantage over any client or competitor. Whereas the recipient may charge clients for the ordinary costs of applying the program, the recipient agrees not to levy a charge, royalty or proprietary usage fee (except to cover any normal copying and/or distribution costs) upon any client for the development or use of the received program. Recipients desiring to modify and remarket the program will be required to comply with a separate agreement. Only minor or temporary modifications will be made to the program (e.g., necessary corrections or changes in the format of input or output) without written approval from the Government. Should the program be furnished by the recipient to a third party the recipient is responsible to that third party for any support and upkeep of the program. Information on the source of the program will be furnished to anyone requesting such information.

The accuracy of this program depends entirely on user-supplied input data. It is the user's responsibility to understand how the input data affects the program output and to use the output data only as intended.

All documents and reports conveying information obtained as a result of the use of the program by the recipient will acknowledge the Corps of Engineers, Department of the Army, as the origin of the program. All such documentation will state the name and version of the program used by the recipient.

Foreword

This work was performed for the U.S. Army Engineering and Housing Support Center (USAEHSC) under the work units A896-NN-TS9 entitled "Imagery Data for Training Area Management," A896-NN-TF9 entitled "Terrain Modeling for Planning Training Events and Natural Resources Management," and A896-NN-TJ9 entitled "GRASS Application Macros." Additional sponsorship came from the U.S. Department of Agriculture Soil Conservation Service (SCS) Cartographic and Geographic Information Systems Division under the work unit RD8P69NVC8 entitled "Enhancements to SCS-GRASS." The USAEHSC Technical Monitor was Ms. Jamie Clark of the Natural and Cultural Resources Division. The SCS Technical Monitor was Mr. Dick Liston.

The authors would like to acknowledge Ms. Mary Martin for her assistance in reviewing, editing, and preparing this document.

This work was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. R.K. Jain is Chief of USACERL-EN.

COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

Table of Contents

Chapter 1

Introduction

1.1. Background

The Geographic Resources Analysis Support System (GRASS) is a geographic information system (GIS) designed and developed by researchers at the U.S. Army Construction Engineering Research Laboratory (USACERL). GRASS provides software capabilities suitable for organizing, portraying and analyzing digital spatial data.

Since the first release of GRASS software in 1985, the number of users and applications has rapidly grown. Because GRASS is distributed with source code, user sites (including many government organizations, educational institutions, and private firms) are able to customize and enhance GRASS to meet their own requirements. While researchers at USACERL still maintain and support GRASS, and still develop and organize new versions of GRASS for release, programmers at numerous sites now work directly with GRASS source code.

1.2. Objective

Those who work with GRASS source code need detailed information on the structure and organization of the software, and on procedures and standards for programming and documentation. The objective of this manual is to provide the necessary information for programmers to understand and enhance GRASS software.

1.3. Approach

GRASS software is continuously updated and improved. Software enhancements are developed at various sites, and submitted to USACERL to be shared with other sites and included in future releases of GRASS. Improvements to the code are periodically incorporated into new releases (which occur approximately once per year).

With each new release of GRASS, more and more sites have begun working directly with GRASS source code. Sites are encouraged to use standard procedures in development of new GRASS capabilities. Sites that develop GRASS software are encouraged to learn and use GRASS programming libraries, and to use standard procedures for coding, commenting and documenting software. The use of GRASS libraries and conventions will:

(1) Eliminate duplication of functions that already exist in GRASS libraries;

(2) Increase the capability of multiple sites to share enhancements;

(3) Reduce problems in adapting contributed GRASS capabilities to new data structures and new versions of GRASS software;

(4) Provide some common elements (such as documentation and user interfaces) for users who use code contributed from multiple sites, and reduce the learning curve associated with each contributed capability.

The first GRASS Programmer's Manual was developed for GRASS 2.0 (released by USACERL in 1987). However, there were numerous and fundamental changes made in GRASS 3.0 (released in 1988). Rather than revise the existing Programmer's Manual, USACERL researchers elected to draft a new and more complete GRASS Programmer's Reference Manual for GRASS 3.0. The approach used in the development of this manual involves a systematic effort to describe GRASS development guidelines, user interfaces, data structures, programming libraries and peripheral drivers.

1.4. Scope

Information in this manual is valid for GRASS version 3.0, released in November, 1988. As changes are made to GRASS libraries, data structures, and user interfaces, elements in this manual will require updating. Plans to perform updates, and the availability of these updates, will be announced in the newsletter *GRASSClippings* and other GRASS information forums.

1.5. Mode of Technology Transfer

Army and Corps of Engineer organizations can aquire GRASS software from USACERL. Several other federal organizations provide distribution and support services for GRASS within their own agencies, and several educational institutions and private firms also provide distribution, training and support services for GRASS. Current information on the status and availability of services for GRASS can be obtained from the GRASS Information Center.[1]

[1] See §*1.6 GRASS Information Center* [p. 4] for phone numbers and mail addresses.

This manual should prove to be a valuable resource facilitating GRASS software development efforts at the numerous government agency, educational institutions and private firms that now use GRASS and plan to modify, enhance or customize the software. Sites that develop new analytical capabilities or peripheral drivers for GRASS are encouraged to share their products with others in the GRASS/GIS user community. To facilitate this sharing process among user, support and development sites, several forums have been established. These include the following:

The GRASS Information Center,

The GRASS Inter-Agency Steering Committee,

An annual GRASS/GIS User Group Meeting,

GRASSClippings, a quarterly newsletter, and

GRASSNET, an electronic mail and software retrieval forum.

The **GRASS Information Center** maintains: (1) a set of publications on GRASS and GRASS-related items, (2) updated information on locations that distribute and support GRASS software and on training courses for GRASS, (3) the mailing list for the newsletter *GRASSClippings*, and (4) updated information on the status of GRASS user group meetings and software releases.

The **GRASS Inter-Agency Steering Committee** is an informal organization with members from government agencies and other organizations that use, support and enhance GRASS. This organization sponsors the annual User Group Meeting and the quarterly newsletter. It holds at least two meetings annually to share and coordinate GRASS plans among the participating agencies.

The annual **GRASS/GIS User Group Meeting** is hosted each year by one of the member agencies of the Steering Committee. Papers, demonstrations, and discussion panels present GRASS applications and software development issues. The meeting provides opportunities for current and potential users to share and demonstrate new GRASS software.

The **GRASSClippings** newsletter is published, approximately four times a year, to provide information to anyone interested in GRASS software. The newsletter includes articles on software development, hardware options and applications of GRASS.

GRASSNET is an electronic mail forum that provides a mechanism through which GRASS user and development sites can exchange messages. It can be reached via Arpanet, Internet and other networks. GRASSNET also includes a library of contributed software available for users to retrieve and review. Thus, new software is available before it is integrated into a formal release of GRASS code.

1.6. GRASS Information Center

Sites wishing to contribute code to GRASS, or wanting to participate in any of these GRASS/GIS user community forums, should contact the GRASS Information Center by phone at: (800)-USA-CERL, extension 220 or (217)-373-7220; by U.S. mail at: GRASS Information Center, USACERL, P.O. Box 4005, Champaign, IL, 61824-4005; or by electronic mail at: grass@cerl.cecer.army.mil.

Chapter 2

Development Guidelines

GRASS continues its development with several key objectives as a guide. The programmer should be aware of these and strive to write code that blends well with existing capabilities. All objectives are based on an understanding of the needs of the end-users of GRASS.

2.1. Intended GRASS Audience

GRASS is a general purpose geographic information system. Its intended users are regional land planners, ecologists, geologists, geographers, archeologists, and landscape architects. Used to evaluate broad land use suitability, it is ideal for siting large projects, managing parks, forest, and range land, and evaluating impacts over wide areas. These users are generally NOT equipped to write programs or design a system. In many cases they have never used a computer or even a keyboard.

REGIONAL PLANNING TOOL -

GRASS is designed for planning at the county, park, forest, or range level. It is suitable for planning at a macro scale where the land uses are larger than 30 meters (or so, depending on the database resolution). As yet, no. GRASS tools exist for the modeling and simulation of traffic, electrical, water, and sewage infrastructure loads, or for the precise positioning of urban structures.

UTM-REFERENCED -

To facilitate area calculations, a planimetric projection was desired for initial GRASS development. Funding was provided through Army military installations which were familiar with the Universal Transverse Mercator (UTM) projection. Due to these factors, GRASS developed around the UTM coordinate system.[1]

INTERACTIVE -

GRASS has a strong interactive component. Its multi-level design allows users to work either at a very user-friendly level, at a more flexible command level, or at

[1] The UTM projection allows GRASS to assume equal area cells anywhere in the database. It also makes distance calculations simple and straightforward. This will change as future releases allow other coordinate systems (e.g., longitude/latitude). The changes will probably not affect overlay operations, but will most likely change the methodology for distance and area calculations.

a programming level.

GRAPHIC-ORIENTED -

Many of the functions can be accompanied by graphic output results.

FOR NON-PROGRAMMER -

Users of GRASS are often first-time users of a computer. To this end, it is important that the programmer take the extra time to provide on-line help, clear prompts, and user tutorials.

INEXPENSIVE -

GRASS can run on microcomputers in the under-$10,000 range. Higher-cost equipment should be necessary only for providing faster analyses, and more disk and memory space.

PORTABLE -

This system is intended to be as portable as possible. At the November 1986 User Group meeting, groups interested in GRASS resoundingly stated that portability was the number one concern, ranking firmly above speed and user-friendliness. GRASS code must be compilable on a wide variety of hardware configurations.

2.2. Programming Standards

Programming is done within the following guidelines.

UNIX-ORIENTED -

Primarily for the purpose of portability, GRASS will continue its development under the UNIX operating system environment. Programmers should accommodate both AT&T (System 5) and Berkeley (UCB 4.2) UNIX.

C LANGUAGE -

All code is written in the C programming language. Some Fortran 77 code has occasionally been adopted into the system, but problems with portability, efficiency, and legibility have resulted in most Fortran programs being rewritten in C.

FUNCTION LEVELS -

GRASS is designed within a functional level scheme. Each level is designed to perform particular functions. Programming must be done within this scheme. Briefly, these levels are as follows:

Full Interactive Level -

The new and occasional user works at this level. As of the first writing of this document, only one program, the GRASS menu, exists at this level. It is expected that specialized models, natural language interfaces, graphic popup menu front-ends, and fancier menus will be developed in the future. Programs developed at this level may be specifically designed for one hardware arrangement.

Command Interactive Level -

This is the level most used. Using the user's login shell, GRASS commands are made available through modification of the **PATH** variable. Commands at this level are highly interactive. Help and on-line manual commands are available. Historically, these programs have included both user interface and program function capabilities. In the future, more and more commands at this level will actually contain only user interface code; after the user is thoroughly interrogated, a command line will be constructed which then drives a program at the Command Level:

Command Level -
: Commands at this level form the G, D, P, etc. languages. They are distinguished by being non-interactive. All information necessary for the execution of the command is provided either in the command line or in the standard input stream (with no prompting). Built on top of these commands may be commands at either of the above two levels. The advanced user who wants greater flexibility in the analysis options may use these directly. Further, the system analyst can use these commands as a high-level GIS programming language in concert with other UNIX utilities.

Programming Level -
: For even greater flexibility in the application of GRASS, a user has the opportunity to program GRASS functions in the C language. The main restrictions here are that the programmer use the existing GRASS function libraries to the greatest extent possible, and support both AT&T and Berkeley UNIX.

Library Level -
: Work at the library level should be done with the cooperation and approval of one group. At this writing, that group is the GRASS programming staff at USACERL. Those functions most critical are those that interface the data. It is believed that these functions will be more permanent than the database. Though the database may change, these functions (and the programming environment) will not.

2.3. Documentation Standards

GRASS is a public domain system. While such systems are usually inexpensive to new sites wishing to adopt them, costs incurred in putting up the system, modifying the code, and understanding the product can be very high. To minimize these costs, GRASS programs shall be thoroughly documented at several levels.

Source code -
: The source code for the functions should be liberally sprinkled with descriptive variables, algorithm explanations, and function descriptions.

On-line help -
: Brief help/information will be available for the new user of a program.

On-line manual -
: Manual entries in the style of the UNIX manual entries will also be available to the user.

Tutorial -

The tools that are more involved or difficult to use shall be accompanied by tutorial documents which teach a user how to use the code. These have been written in nroff/troff using the *ms* macro package.[2] Final documents have been kept separate from the GRASS directories, though it is suggested that they appear with appropriate "makefiles" under $GISBASE/tutorials.[3]

[2] This package, invoked with the -ms option to nroff, is documented in section 7 of the UNIX manual.

[3] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p. 51*] for details.

Chapter 3

Multi-Level

As introduced in the previous section, the overall GRASS design incorporates several levels:

Full Interactive Level
Command Interactive Level
Command Level
Programming Level
Library Level

Each level is associated with a different type of user interface.

3.1. General User

The general GRASS user is someone with a skill in some resource area (e.g., planning, biology, agronomy, forestry, etc.) in which GRASS can be used to support spatial analysis. Such users have no significant computer skills, may be afraid of keyboards, know nothing of UNIX, and may struggle with the learning curve for GRASS. Such users should select the **Full Interactive Level,** where they are guided through the options in a friendly way. Programs written at this level may take many forms in the future. The promise of a natural language capability may take form here. Current success with graphic menu systems in other applications will lead to pleasant graphic screens with pull-down menus. Interfaces developed at this level (and this level only) may be hardware-specific. GRASS may take the form of a voice-activated system with fancy AI capabilities on one machine, while it is driven by a pull-down menu system which is also tightly interfaced to an RDBMS on another. All versions, however, will rely heavily on the consistent commands available at the **Command Level.** As of this writing the menu version of GRASS is the sole representative of this interface. It is anticipated that specialized analysis models using little or no user input will be developed shortly, making use of UNIX shell scripts and **Command Level** commands. These will be written by system analysts and will require no knowledge of C programming. Until improvements in speed and cost of hardware and flexibility of software are available, most general users of GRASS interface the system through the **Command Interactive Level** level.

The **Command Interactive Level** requires some knowledge of UNIX. The user starts up the GRASS tools individually through the UNIX shell (commonly Bourne or Csh). Once a GRASS tool is started, the user enters a very friendly and interactive environment. Users are **not** prompted through graphics. Prompting is restricted to written interaction.

3.2. GRASS Programmer

The GRASS programmer, using an array of programming libraries, writes interactive tools and command line tools. Programmers must keep in mind that **Full Interactive Level** tools will be:

a. Written for the occasional user;
b. Verbose in their prompting;
c. Have available lots of help; and
d. Give the user few options.

The programmer also writes **Command Level** tools. These:

a. Can run in batch (background) mode;
b. Take input from the command line, standard input, or a file;
c. Can run from a shell; and
d. Operate with a standard interface.

GRASS programmers should keep the following design goals in mind:

a. Consistent user interface;
b. Consistent database interface;
c. Functional consistency;
d. Installation consistency; and
e. Code portability.

As much as possible, interacting with the user (e.g., prompting for database files, or full screen input prompting) must not vary in style from program to program. All GRASS programs must access the database in a standard manner. Functional mechanisms (such as automatic windowing and masking of cell data) which are independent of the particular algorithm must be incorporated in most GRASS programs. Users must be able to install GRASS (data, programs, and source code) in a consistent manner. Finally, GRASS programs must compile and run on most (if not all) versions of UNIX. To achieve these goals, all programming must adhere to the following guidelines:

Use C language -

This language is quite standard, ensuring very good portability. All of the GRASS system libraries are written in C. With very few exceptions, the GRASS programs are also written in C. While UNIX machines offer a Fortran 77, experience has shown that F77 code is not as portable or predictable when moved between machines. Existing Fortran code has occasionally been adopted, but programmers often prefer to rewrite the code in C.

Use Bourne shell -
GRASS also makes use of the UNIX command interpreter to implement various function scripts, such as menu front-ends to a suite of related functions, or application macros combining GRASS command level tools and UNIX utilities. Portability requires that these scripts be written using the Bourne Shell (/bin/sh) and no other. See §*24 Writing GRASS Shell Scripts* [p.229].

Do not access data directly -
The GRASS database is **NOT** guaranteed to retain its existing organization and structure. These have changed in the past; however, the library function calls to the data have remained more consistent over time. Plans do exist to significantly change the data organization. While the programmer should be aware of the data capabilities and limitations, it should not be necessary to open and read data files directly.

Use Gmake -
GRASS code is compiled using the *Gmake* command, which is a front-end to the UNIX *make* utility. *Gmake* combines some pre-defined variables with a file called *Gmakefile* in the source directory to create a proper makefile, and then runs *make* to compile the program. Each source code directory must have a *Gmakefile,* written by the programmer, containing instructions for making the binary executables, manual and help entries, and other items from the directory's contents. The *Gmakefile* does not contain hard-coded references to programs, libraries, or directories outside the current directory. Variables defining these items are used instead. *Gmakefiles* remain identical system to system thus providing consistency for system installation and compilation. See §*11 Compiling GRASS Programs Using Gmake* [p.55] for more details.

Use GRASS libraries -
Use of the existing GRASS programming libraries speeds up programming efforts. While user and data interface may make up a large part of a new program, the programmer, using existing library functions, can concentrate primarily on the analysis algorithms of the new tool. Such programs will maintain a consistency in data access and (more importantly) a degree of consistency in the user interface. Each library has a definition in *Gmake* to aid in linking the library during program compilation and loading. The libraries are listed briefly below.

GIS Library. This library contains all of the routines necessary to read and write the GRASS grid cell data layers and their support files. A standardized method to prompt the user for map names is available. The library also provides some general purpose tools like memory allocation, buffer zeroing, string analysis, and data searching. Ninety-nine percent of all GRASS programs use routines from this library. See §*12 GIS Library* [p.63].

Segment Library. For programs that need random access to an entire map layer, the segment library provides an efficient paging scheme for grid cell maps. While virtual memory operating systems perform paging, this library provides better control and efficiency of paging. See §*19 Segment Library* [*p. 179*].

Dig Library. While GRASS is primarily a grid cell analysis and display system, it also has some vector capabilities. The principal uses of GRASS vector files are to generate raster maps and to plot base maps on top of grid cell displays. However, it is anticipated that additional analysis and data import capabilities will be added to the vector database. Many vector formats exist in the GIS world, but GRASS has chosen to implement its own internal vector format. The format is a variant of arc-node. The **Dig Library** provides access to the GRASS vector database. See §*13 Dig Library* [*p. 123*].

Vask Library. This screen-oriented user interface is widely used in the GRASS programs. It provides the programmer with a simple means for displaying a particular screen layout, with defined fields where the user is prompted for answers. The user, using the carriage return (or line-feed) and ctrl-k keys, moves from prompt to prompt, filling an answer into each field. When the ESC (escape) key is struck, the answers are provided to the program for analysis. Users have found this interface pleasant and consistent. See §*20 Vask Library* [*p. 187*].

Graphics Libraries. Graphics design has been a difficult issue in GRASS development. To ensure portability and competitive bidding, GRASS has been designed with graphics flexibility in mind. This has meant restricting graphics to a minimal set of graphics primitives, which generally do not make full use of the graphics capabilities on all GRASS machines. Two libraries, **displaylib** and **rasterlib**, are involved in generating graphics. The **rasterlib** contains the primitive graphics commands used by GRASS. At run time, programs using this library communicate (through fifo files) with another program which translates the graphics commands into graphics on the desired device. Each time the program runs, it may be talking to a different graphics device. Functions available in the **rasterlib** include color setting and choosing, line drawing, mouse access (with three types of cursor), raster drawing operations, and text drawing. Generally, this library is used in conjunction with the **displaylib**. The **displaylib** provides graphics window management routines, coordinate conversion capabilities, and grid cell data to raster graphic conversions. See §*16 Display Graphics Library* [*p. 159*] and §*15 Raster Graphics Library* [*p. 147*].

3.3. Driver Programmer

GRASS programs are written to be portable. To this end, a tremendous amount of modularity is designed into the system. Throughout its development, GRASS programs have become increasingly specialized. The original monolithic approach continues to fragment into ever smaller pieces. Smaller pieces will allow future developers and users ever more variability in the mixing of the tools.

This modularity has been manifested in the graphics design. A graphics-oriented tool connects, at run time, to a graphics driver (or translator) program. This separate process understands the standard graphics commands generated by the GRASS tool, and makes the appropriate graphics calls to a particular graphics device. Each graphics device available to a user is accompanied by a driver program, and each program understands the graphics calls of the application program. Porting of GRASS to a new system primarily means the development of one new graphics driver. See §22 *Writing a Graphics Driver* [p.207].

Those sites using the digitizing software of GRASS must also provide driver routines for their digitizer. These routines, unlike the above graphics calls, are compiled directly into the digitizing programs. See §21 *Writing a Digitizer Driver* [p.195].

Similarly, GRASS sites may wish to write code to support different hardcopy color printers (inkjet, thermal, etc.). See §23 *Writing a Paint Driver* [p.215].

3.4. GRASS System Designer

To date, GRASS system design has been done at one location: USACERL. One, and only one site must be responsible for the design of the system at the database and fundamental library level. As the software is public domain, sites are free to do their own work. However, the strength of future GRASS releases depends on cooperation and sharing of software. Therefore, it is strongly encouraged that **database design and database library development be fully coordinated with GRASS staff at USACERL.**

Chapter 4

Database Structure

This section presents the programmer interested in developing new applications with an explanation of the structure of the GRASS databases, as implemented under the UNIX operating system.

4.1. Programming Interface

GRASS Programmers are provided the *GIS Library*, which interfaces with the GRASS database. It is described in detail in §*12 GIS Library* [*p.63*]. Programmers should use this library to the fullest extent possible. In fact, a programmer will find that use of the library will make knowledge of the database structure almost unnecessary.

GRASS programs are not written with specific database names or directories hard-coded into them. The user is allowed to select the database or change it at will. The database name, its location within the UNIX file system, and other related database information are stored as variables in a hidden file in the user's home directory.[1] GRASS programs access this information via routines in the *GIS Library*. The variables that specify the database are described briefly below; see §*10 Environment Variables* [*p.51*] for more details about these and other environment variables.

Note. These GRASS environment variables may also be cast into the UNIX environment to make them accessible for shell scripts.[2] In the discussion below, these variables will appear preceded by a dollar sign ($). However, C programs should not access the GRASS environment variables using the UNIX getenv( ) since they do not originate in the UNIX environment. GIS Library routines, such as *G_getenv*(*p.67*), must be used instead.

[1] This file is *grassrc* under GRASS 3.0.

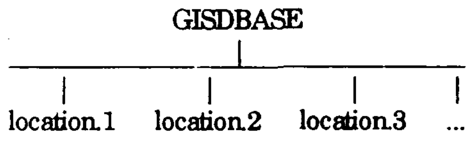
[2] using *gisenv*; see §*24 Writing GRASS Shell Scripts* [*p.229*]

4.2. Gisdbase

The database for GRASS makes use of the UNIX hierarchical directory structure. The top level directory is known as GISDBASE. Users specify this directory when entering GRASS. The full name of this directory is contained in the UNIX environment variable $GISDBASE, and is returned by library routine *G_gisdbase*(*p.67*).

4.3. Locations

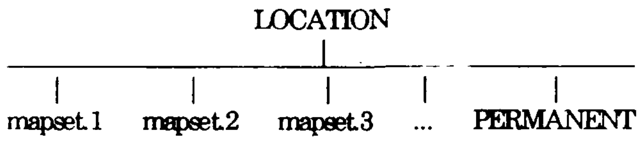
Subdirectories under the GISDBASE are known as locations. Locations are independent databases. Users select a location when entering GRASS. All database queries and modifications are made to this location only. It is not possible to simultaneously access multiple locations. The currently selected location is contained in the environment variable $LOCATION_NAME, and is returned by the library routine *G_location*(*p.66*).



When users select a location, they are actually selecting one of the location directories.

4.4. Mapsets

Subdirectories under any location are known as mapsets. Users select a mapset when entering GRASS. New mapsets can be created during the selection step. The selected mapset is known as the current mapset. It is named in the environment variable $MAPSET and returned by *G_mapset*(*p.66*).



Modifications to the database can only be made in the current mapset. Users may only select (and thus modify) a mapset that they own (i.e., have created). However, data in all mapsets for a given location can be read by anyone (unless prevented by UNIX file permissions). See §*4.7 Database Access Rules* [*p.20*] for more details.

When users select a mapset, they are actually selecting one of the mapset directories.

Note. The full UNIX directory name for the current mapset is $GISDBASE/$LOCATION_NAME/$MAPSET and is returned by the library routine

G_location_path(p. 67).

Note. Each location will have a special mapset called PERMANENT that contains non-volatile data for the location that all users will use. However, it also contains some information about the location itself that is not found in other mapsets. See §*4.6 Permanent Mapset* [p. 19].

4.5. Mapset Structure

Mapsets will contain *files* and subdirectories, known as database *elements*. In the diagram below, the elements are indicated by a trailing /.

```
                                  MAPSET
                                     |
      ____________________________________________________________________
      |              |         |        |         |           |         |
 SEARCH_PATH       WIND      cats/    cell/     paint/     windows/    ...
```

4.5.1. Mapset Files

The following is a list of some of the mapset files used by GRASS programs:

files	function
GROUP	current imagery group
SEARCH_PATH	mapset search path
WIND	current window

This list may grow as GRASS grows. The GROUP file records the current imagery group selected by the user, and is used only by imagery functions. The other two files are fundamental to all of GRASS. These are WIND and SEARCH_PATH.

WIND is the current window. This file is created when the mapset is created and is modified by the *window* command. The contents of WIND are returned by *G_get_window*(p. 77). See §*9.1 Window* [p. 47] for a discussion of the GRASS window.

SEARCH_PATH contains the *mapset search path*. This file is created and modified by the *mapsets* command. It contains a list of mapsets to be used for finding database files. When users enter a database file name without specifying a specific mapset, the mapsets in this search path are searched to find the file. Library routines that look for database files use the mapset search path to find database files. See §*4.7.1 Mapset Search Path* [p. 20] for more information about the mapset search path.

4.5.2. Elements

Subdirectories under a mapset are the database *elements*. Elements are not created when the mapset is created, but are created dynamically when referenced by the application programs.[3] Mapset data reside in files under these elements.

The dynamic creation of database elements makes adding new database elements simple since no reconfiguration of existing mapsets is required. However, the programmer must be aware of the database elements already used by currently existing programs when creating new elements. Furthermore, as development occurs outside USACERL, guidelines must be developed for introducing new element names to avoid using the same element for two diverse purposes.

Programmers using shell scripts must exercise care. It is not safe to assume that a mapset has all, or any, database elements (especially brand new mapsets). Certain GRASS commands automatically create the element when it is referenced (e.g., *Gask*). In general, however, elements are only created when a new file is to be created in the element. It is wise to explicitly check for the existence of database elements.

[3] See §*12.5.6 Creating and Opening a New Database File* [p. 74].

Here is list of some of the elements used by GRASS programs written at USACERL:

element	function
cell	data layers (cell files)
cellhd	header files for data layers
cats	category information for data layers
colr	color table for data layers
colr2	secondary color tables for data layers
cell_misc	miscellaneous cell support files
hist	history information for data layers
dig	binary vector data
dig_ascii	ascii vector data
dig_att	vector attribute support
dig_plus	vector topology support
dig_cats	vector category label support
reg	digitizer point registration
bdlg	binary dlg files
dlg	ascii dlg files
icons	icon files used by *paint*
paint	label and comment files used by *paint*
group	imagery group support data
site_lists	site lists for *sites* program
windows	pre-defined windows
COMBINE	*combine* scripts
WEIGHT	*weight* scripts

Note. The mapset database elements can be simple directory names (e.g., cats, colr) or multi-level directory names (e.g., paint/labels, group/xyz/subgroup/abc). The library routines that create the element will create the top level directory and all subdirectories as well.

4.6. Permanent Mapset

Each location must have a PERMANENT mapset. This mapset not only contains original map layers and vector files that must not be modified, but also two special files that are only found in this mapset. These files are MYNAME and DEFAULT_WIND and are never modified by GRASS software.

MYNAME contains a single line descriptive name for the location. This name is returned by the routine *G_myname*(*p. 66*).

DEFAULT_WIND contains the default window for the location. This file is used to initialize the WIND file for new mapsets. The contents of this file are returned by *G_get_default_window*(*p. 78*).

4.7. Database Access Rules

GRASS database access is controlled at the mapset level. There are three simple rules:

1 A user can select a mapset as the *current* mapset only if the user is the owner of the mapset directory (see §*4.4 Mapsets* [*p.16*]).

2 GRASS will create or modify files only in the current mapset.

3 Files in all mapsets may be read by anyone (see §*4.7.1 Mapset Search Path* [*p.20*]) unless prohibited by normal UNIX file permissions (see §*4.7.2 UNIX File Permissions* [*p.20*]).

4.7.1. Mapset Search Path

When users specify a new data file, there is no ambiguity about the mapset in which to create the file: it is created in the current mapset. However, when users specify an existing data file, the database must be searched to find the file. For example, if the user wants to display the "soils" cell file, the system looks in the various database mapsets for a cell file named "soils." The user controls which mapsets are searched by setting the *mapset search path,* which is simply a list of mapsets. Each mapset is examined in turn, and the first "soils" cell file found is the one that is displayed. Thus users can access data from other users' mapsets through the choice of the search path.

Users set the search path using the *mapsets* or *Gmapsets* commands.

Note. If there were more than one "soils" file, the mapset search mechanism returns the first one found. If the user wishes to override the search path, then a specific mapset could be specified along with the file name. For example, the user could request that "soils in PERMANENT" be displayed.

4.7.2. UNIX File Permissions

GRASS 3.0 creates all files with read/write permission enabled for everyone and directories with read/write/search permission enabled for everyone.[4] This implies that all users can read anyone else's data files.[5]

[4] This means -rw-rw-rw for files, and drwxrwxrwx for directories. It is accomplished by setting the umask to 0 in all GRASS programs.

[5] It also implies that all users can modify and remove anyone else's files. Although GRASS code won't create or modify files in other users' mapsets, the database is wide open to standard UNIX access. A planned improvement will be to set the umask to 022 so that the permissions are -rw-r--r-- for files and drwxr-xr-x for directories. This will allow complete control of access to the database.

While there is no mechanism currently in GRASS to modify these access permissions, access to a mapset can be controlled by removing (or adding) the read and search permissions on the mapset directory itself using the UNIX *chmod* command, without adversely affecting GRASS programs. For example, suppose that the full UNIX name of the mapset is */grass/data/spearfish/xyz*. To set the permissions so that only the mapset owner can access the *xyz* mapset:

```
chmod 0700 /grass/data/spearfish/xyz
```

To reset the permissions so that everyone can read from the mapset:

```
chmod 0755 /grass/data/spearfish/xyz
```

Warning. Since the PERMANENT mapset contains global database information, all users must have read and search access to the PERMANENT mapset directory.[6] Don't remove the read and search permissions from PERMANENT.

[6] PERMANENT has the DEFAULT_WIND and MYNAME files. This is a minor design flaw. Global database information should be kept in the database, but not in any of the mapsets. All mapsets could then be treated equally.

Chapter 5

Grid Cell Maps

This chapter provides an explanation of how grid cell map layers are accommodated in the GRASS database.[1]

5.1. What is a Grid Cell Map Layer?

GRASS grid cell map layers can be conceptualized, by the GRASS programmer as well as the user, as representing information from a paper map, a satellite image, or a map resulting from the interpretation of other maps. Usually the information in a map layer is related by a common theme (e.g., soils, or landcover, or roads, etc.).

GRASS grid cell data are stored as a matrix of *grid cells*. Each grid cell covers a known, rectangular (generally square) patch of land. Each cell is assigned a single integer attribute value called the *category* number. For example, assume the land cover map covers a state park. The grid cell in the upper-left corner of the map is category 2 (which may represent prairie); the next grid cell to the east is category 3 (for forest); and so on.

land cover

2	3	3	3	4	4
2	2	3	3	4	4
2	2	3	3	4	4
1	2	3	3	3	4
1	1	1	3	3	4
1	1	3	3	4	4

1 = urban	3 = forest
2 = prairie	4 = wetlands

In addition to the cell data file itself, there are a number of support files for the grid cell map layer. The files which comprise a grid cell map layer all have the same name, but each resides in a different database directory under the mapset. These

[1] The descriptions given here are for GRASS 3.0 data formats only. Previous formats, still supported by GRASS but no longer generated, are described in documents from earlier releases of GRASS.

database directories are:

directory	function
cell	grid cell data files
cellhd	grid cell header files
cats	map layer category information
colr	map layer color tables
colr2	alternate map layer color tables
hist	map layer history information
cell_misc	miscellaneous map layer support information

For example, a map layer named *soils* would have the files *cell/soils, cellhd/soils, colr/soils, cats/soils,* etc.

Note. Database directories are also known as database *elements*. See *§4.4 Mapsets* [*p. 16*] for a description of database elements.

Note. *GIS Library* routines which read and write cell files are described in *§12.8 Cell File Processing* [*p. 80*].

5.2. Grid Cell File Format

The programmer should think of the grid cell data file as a two-dimensional matrix (i.e., an array of rows and columns) of integer values. Each cell is stored in the file as one to four 8-bit bytes of data. An NxM cell file will contain N rows, each row containing M columns (or bytes) of data.

The physical structure of a cell file can take one of 3 formats: uncompressed, compressed, or reclassed.

Uncompressed format. The uncompressed cell file actually looks like an NxM matrix. Each byte (or set of bytes for multi-byte data) represents a cell of the map layer. The physical size of the file, in bytes, will be *rows*cols*bytes-per-cell.*

Compressed format. The compressed format uses a run-length encoding schema to reduce the amount of disk required to store the cell file. Run-length encoding means that sequences of the same data value are stored as a single byte repeat count followed by a data value. If the data is single byte data, then each pair is 2 bytes. If the data is 2 byte data, then each pair is 3 bytes, etc. (see **Multi-byte data format** below). The rows are encoded independently; the number of bytes per cell is constant within a row, but may vary from row to row. Also if run-length encoding results in a larger row, then the row is stored non-run-length encoded. And finally, since each row may have a different length, there is an index to each row stored at the beginning of the file.

Reclass layers. Reclass map layers do not contain any data, but are references to another map layer along with a schema to reclassify the categories of the referenced map layer. The reclass cell file itself contains no useful information. The reclass information is stored in the cell header file.

Multi-byte data format. When the data values in the cell file require more than one byte, they are stored in *big-endian* format,[2] which is to say as a base 256 number with the most significant digit first.

Examples:

cell value		base 256	stored as			
868	=	3*256 + 100	3	100		
137,304	=	$2*256^2 + 24*256 + 88$	2	24	88	
174,058,106	=	$10*256^3 + 95*256^2 + 234*256 + 122$	10	95	234	122

Negative values are stored as a signed quantity, i.e., with the highest bit set to 1:[3]

cell value		base 256	stored as				
-1	=	-(1)	1	0	0	0	1
-868	=	-(3*256 + 100)	1	0	0	3	100
-137,304	=	$-(2*256^2 + 24*256 + 88)$	1	0	2	24	88
-174,058,106	=	$-(10*256^3 + 95*256^2 + 234*256 + 122)$	1	10	95	234	122

All data values in a given row are stored using the same number of bytes. This means that if the value 868, which uses 2 bytes, occurred in a row that uses 3 bytes to represent the largest data value, 868 would be stored as $\boxed{0\,|\,3\,|\,100}$

Also, one row may only require 2 bytes to store its data values, another 4 bytes, and yet another 1 byte. The rows are stored independently and would be stored using 2 bytes, 4 bytes, and 1 byte respectively.

File portability. The multi-byte format described above is, except for negative values,

[2] The fact that the values are stored *big-endian* should not be construed to mean that the machine architecture must also be *big-endian*. The programs which read cell files perform the necessary arithmetic to construct the value. They do NOT assume anything about byte ordering in the cpu.

[3] This means that the value is stored using as many bytes as required by an integer on the machine (usually 4).

machine-independent. If cell files are to be moved to a machine with a different cpu, or accessed using a heterogeneous network file system (NFS), the following guidelines should be kept in mind. All *3.0 format* cell files will transfer between machines, with two restrictions: (1) if the file contains negative values, the size of an integer on the two machines must be the same; and (2) the size of the file must be within the seek capability of the lseek( ) call.[4] The *pre-3.0 compressed* format is not stored in a machine-independent format, and cannot generally be used for inter-machine transfer. It will transfer if the two machines have the same integer and long integer format.

5.3. Cell Header Format

The cell file itself has no information about how many rows and columns of data it contains, or which part of the earth the layer covers. This information is in the cell header file. The format of the cell header depends on whether the map layer is a regular map layer or a reclass layer.

Note. *GIS Library* routines which read and write the cell header file are described in *§12.9.1 Cell Header File* [*p.89*].

5.3.1. Regular Format

The regular map layer cell header contains the information describing the physical characteristics of the cell file. The cell header has the following fields:

cell header

proj:	1
zone:	18
north:	4660000.00
south:	4570000.00
east:	770000.00
west:	710000.00
e-w resol:	50.00
n-s resol:	100.00
format:	0
compressed:	0

proj, zone

The *proj*ection field specifies the type of cartographic projection:

0 is unreferenced x,y (imagery data)
1 is UTM
2 is State Plane[5]

Others may be added in the future. The *zone* field is the projection zone. In the

[4] This usually means that the size of a long integer on the two machines is the same.

[5] State Plane is not yet fully supported in GRASS.

example above, the projection is UTM, the zone 18.

north, south, east, west

The geographic boundaries of the cell file are described by the *north, south, east,* and *west* fields. These values describe the lines which bound the map at its edges. These lines do NOT pass through the center of the cells at the edge of the map, but along the edge of the map itself.

n-s resol, e-w resol

The fields *e-w resol* and *n-s resol* describe the size of each grid cell in the map layer in physical measurement units (e.g., meters in a UTM database). They are also called the grid cell resolution. The *n-s resol* is the length of a grid cell from north to south. The *e-w resol* is the length of a grid cell from east to west. As can be noted, cells need not be square.

format

The *format* field describes how many bytes per cell are required to represent the grid cell data. 0 means 1 byte, 1 means 2 bytes, etc.

compressed

The *compressed* field indicates whether the grid cell file is in compressed format or not: 1 means it is compressed and 0 means it isn't. If this field is missing, then the grid cell was produced prior to GRASS 3.0 and the compression indication is encoded in the grid cell itself.

rows, cols

The rows and columns of the grid matrix are not stored in the cell header. They are computed from the geographic boundaries as follows:

```
rows = (north  – south)  /  (ns resol)
cols  = (east    – west)  /  (ew resol)
```

5.3.2. Reclass Format

If the cell file is a reclass cell file, the cell header does not have the information mentioned above. It will have the name of the referenced cell file and the category reclassification table.

reclass cell header

reclass		
name:	county	
mapset:	PERMANENT	
#5		*first category in reclass*
1		*5 is reclassified to 1*
0		*6 is reclassified to 0*
1		*7 is reclassified to 1*
0		*8 is reclassified to 0*
2		*9 is reclassified to 2*

In this case, the library routines will use this information to open the referenced cell file in place of the reclass cell file and convert the cell file data according to the reclass scheme. Also, the referenced cell header is used as the cell header.

The # as the first character of the fourth line in the file indicates that this is a 3.0 format reclass cell header file.

5.4. Cell Category File Format

The category file contains the largest category value which occurs in the data, a title for the map layer, an automatic label generation capability, and a one line label for each category.

category file

```
# 5 categories
title for map layer
<automatic label format>
<automatic label parameters>
0:no data
1:description for category 1
2:description for category 2
3:description for category 3
5:description for category 5
```

The # as the first character of the first line in the file indicates that this is a 3.0 format category file. The number which follows it is the largest category value in the cell file. The next line is a title for the map layer. The next two lines are used for automatic label generation. They are used to create labels for categories which do not have explicit labels. (The automatic label capability is not normally used in most map layers, in which case the *format* line is a blank line and the *parameters* line is: 0.0 0.0 0.0 0.0.) Category labels follow on the remaining lines. The format is *cat : label.*

The first four lines of the file are required. The remaining lines need only appear if categories are to be labeled.

Note. *GIS Library* routines which read and write the cell category file are described in §*12.9.2 Cell Category File* [*p. 91*].

5.5. Cell Color Table Format

The color table contains one line of a color description for each category of data, including the "no data" category. The colors are represented as levels of red, green, and blue, where 0 represents the lowest intensity and 255 represents the highest intensity.

color table file

# 4 first color			
255	255	255	*color for category 0*
0	128	128	*color for category 4*
200	128	40	*color for category 5*
255	0	0	*color for category 6*
0	255	0	*color for category 7*
255			*color for category 8*

The # as the first character of the first line in the file indicates that this is a 3.0 format color file. The number which follows is the first data value which has a color (and should be the lowest non-zero category value in the cell file). The next line is the color for category 0. The remaining lines are the colors for the other categories. There are 3 columns representing the red, green, and blue levels respectively. If all 3 values are identical (i.e., a grey scale color), only the red value need be present.

Note that the color file format is a modest attempt to allow color tables for files like elevation, which have their lowest non-zero data value above 1 (often above 1000). In these cases the color table doesn't have to start with 1 and create unused colors.

Note. *GIS Library* routines which read and write the cell color table are described in §*12.9.3 Cell Color Table* [*p.94*].

5.6. Cell History File

The history file contains historical information about the cell file: creator, date of creation, comments, etc. In most applications, the programmer need not be concerned with the history file. It is generated automatically along with the cell file. The GRASS *layer.info* program allows the user to view this information, and the *support* program allows the user to update it.

Note. *GIS Library* routines which read and write the cell history file are described in §*12.9.4 Cell History File* [*p.98*].

5.7. Cell Range File

The range file contains the minimum and maximum values which occur in a cell file. It is generated automatically for all new cell files. This file lives in the *cell_misc* element as "cell_misc/*name*/range" where *name* is the related cell file name.

It contains one line with four integer values. These represent the minimum and maximum negative values, and the minimum and maxmimum positive values in the cell file. If there are no negative values, then the first pair of numbers will be zero. If there are no positive values, then the second pair of numbers will be zero.

Note. *GIS Library* routines which read and write the cell range file are described in §*12.9.5 Cell Range File* [*p.99*].

Chapter 6

Vector Maps

This chapter provides an explanation of how vector map layers are accommodated in the GRASS database.

6.1. What is a Vector Map Layer?

GRASS vector maps are stored in an *arc-node* representation, consisting of non-intersecting curves called *arcs*. An arc is stored as a series of x,y coordinate pairs.[1] The two end-points of an arc are called *nodes*. Two consecutive x,y pairs define an arc *segment*. [2]

The arcs, either singly, or in combination with others, form higher level map features: *lines* [3] (e.g., roads or streams) or *areas* [4] (e.g., farms or forest stands). Arcs that form linear features are sometimes called *lines,* and arcs that outline areas are called *area edges* or *area lines.* [5]

Each map feature is assigned a single integer attribute value called the *category* number. For example, assume a vector file contains land cover information for a state park. One area may be assigned category 2 (perhaps representing prairie); another is assigned category 3 (for forest); and so on. Another vector file which contains road information may have some roads assigned category 1 (for paved roads); other roads may be assigned category 2 (for gravel roads); etc. See §*5.1 What is a Grid Cell Map Layer?* [p.23] for more information about GRASS category values.

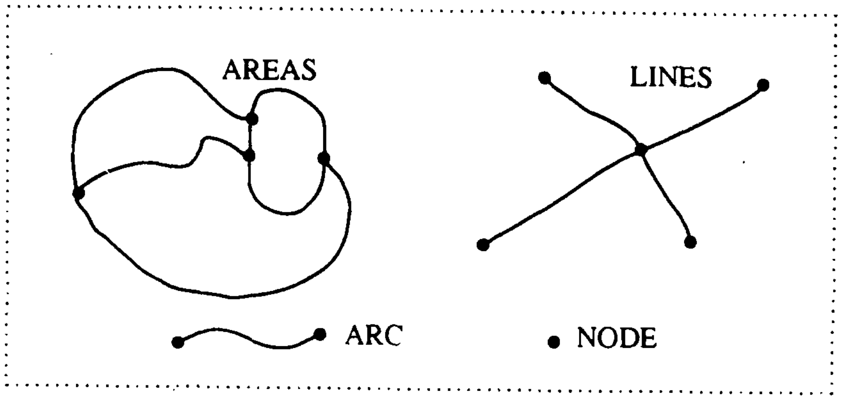
[1] For this reason *arcs* are also called *vectors.*

[2] Arc *segments* are sometimes called *line-segments.*

[3] A *line* here does not mean a straight line between two points. It only means a linear feature.

[4] *Areas* are also called *polygons.* The GRASS vector format does not store the polygons explicitly. They are constructed by finding the particular *arcs* which form the polygon perimeter.

[5] Obviously, there is some confusion in the GIS vector terminology. This is partly due to use of terms that have a common meaning as well as a mathematical meaning. Vector terminology is a subject for much debate in the GIS world.



A vector map layer is stored in a number of data files. The files which comprise a single vector map layer all have the same name, but each resides in a different database directory under the mapset.[6] These database directories are:

directory	function
dig	binary arc file
dig_ascii	ascii arc file
dig_att	vector category attribute file
dig_cats	vector category labels
dig_plus	vector index/pointer file
reg	digitizer registration points

For example, a map layer named *soils* would have the files *dig/soils, dig_att/soils, dig_plus/soils, dig_ascii/soils, dig_cats/soils, reg/soils,* etc.

Note. Vector files are also called *digit* files, since they are created and modified by the GRASS digitizing program *digit.*

Note. When referring to one of the vector map layer files, the directory name is used. For example, the file under the *dig* directory is called the *dig* file.

Note. Library routines which read and write vector files are described in §*13 Dig Library* [*p. 123*].

6.2. Ascii Arc File Format

The arc information is stored in a binary format in the *dig* file. The format of this file is reflected in the ascii representation stored in the *dig_ascii* file. It is the ascii version which is described here.[7]

[6] Database directories are also called *elements.* See §*4.4 Mapsets* [*p. 16*] for a description of database elements.

[7] The programs *import.to.vect, a.b.vect,* and *b.a.vect* convert between the ascii and binary formats.

The *dig_ascii* file has two sections: a header section, and a section containing the arcs.

6.2.1. Header Section

The header contains historical information, a description of the map, and its location in the universe. It consists of fourteen entries. Each entry has a label identifying the type of information, followed by the information. The format of the header is:

label	format	description
ORGANIZATION:	text (max 29 characters)*	organization that digitized the data
DIGIT DATE:	text (max 19 characters)*	date the data was digitized
DIGIT NAME:	text (max 19 characters)*	person who digitized the data
MAP NAME:	text (max 40 characters)*	title of the original source map
MAP DATE:	text (max 10 characters)*	date of the original source map
OTHER INFO:	text (max 72 characters)*	other comments about the map
MAP SCALE:	integer	scale of the original source map
ZONE:	integer	zone of the map (e.g., UTM zone)
WEST EDGE:	real number (double)	western edge of the entire map †
EAST EDGE:	real number (double)	eastern edge of the entire map †
SOUTH EDGE:	real number (double)	southern edge of the entire map †
NORTH EDGE:	real number (double)	northern edge of the entire map †
MAP THRESH:	real number (double)	digitizing resolution ‡
VERTI:	(no data)	marks the end of the header section

The labels start in column 1 and continue through column 14. Labels are uppercase, left-justified, end with a colon, and blank-padded to column 14. The information starts in column 15. For example:

* Currently, GRASS programs which read the header information are not tolerant of text fields which exceed these limits. If the limits are exceeded, the ascii to binary conversion will probably fail.

† The edges of the map describe a window which should encompass all the data in the vector file.

‡ The MAP THRESH is set by the *digit* program. If the data comes from outside GRASS, this field can be set to 0.0.

```
ORGANIZATION:   US Army CERL
DIGIT DATE:     03/18/88
DIGIT NAME:     grass
MAP NAME:       Urbana, IL.
MAP DATE:       1975
OTHER INFO:     USGS sw/4 urbana 15' quad. N4000-W8807.5/7.5
MAP SCALE:      24000
ZONE:           16
WEST EDGE:      383000.00
EAST EDGE:      404000.00
SOUTH EDGE:     4429000.00
NORTH EDGE:     4456000.00
MAP THRESH:     0.00
VERTI:
```

6.2.2. Arc Section

The arc information appears in the second section of the *dig_ascii* file (following *VERTI:* which marks the end of the header section). Each arc consists of a description entry, followed by a series of coordinate pairs. The description specifies both the type of arc (*A* for area edge, or *L* for line[8]), and the number of points (coordinate pairs) in the arc. Then the points follow.

For example:

```
A 5
  4434456.04   388142.16
  4434446.65   388202.64
  4434407.49   390524.38
  4434107.06   390523.59
  4433326.51   390526.48
L 3
  4434862.31   392043.33
  4434872.42   394662.14
  4434871.44   398094.75
A 3
  4454747.38   396579.60
  4454722.69   393539.73
  4454703.68   390786.90
```

In this example, the first arc is an area edge and has 5 points. The second arc is part of a linear feature and has 3 points. The third arc is another area edge and has 3 points.

The arc description has the letter *A* or *L* in the first column, followed by at least one

[8] Other types may be added in the future.

space, and followed by the number of points.[9]

Point entries start with a space, and have at least one space between the two coordinate values.[10]

Note. The points are stored as **y,x** (i.e., north, east), which is the reverse of the way GRASS usually represents geographic coordinates.

Note. If the *digit* program has deleted an arc, the arc type will be represented using a lower case letter (i.e., *l* instead of *L*, *a* instead of *A*). Of course, this will only be manifest when a binary *dig* file with a deleted arc is converted to the ascii *dig_ascii* file.

6.3. Vector Category Attribute File

As was mentioned in §*6.1 What is a Vector Map Layer?* [p.31], each feature in the vector map layer has a *category* number assigned to it. The category number for each map feature is not stored in the *dig* file itself, but in the *dig_att* file.

The *dig_att* file is an ascii file that has multiple entries, each with the same format. Each entry refers to one map feature, and specifies the feature type (area or line), an x,y marker, and a category number.

For example:

```
A    389668.32    4433900.99    7
L    395103.96    4434881.19    2
```

In this example, an area feature is assigned category 7, and a linear feature is assigned category 2.

The x,y marker is used to find the map feature in the *dig* file. It must be located so that it uniquely identifies its related map feature. In particular, an area marker must be inside the area, and a line marker must be closer to its related line than to any other line (preferrably on the line) and not at a node.

If multiple entries identify the same map feature, only one will be used (currently the last one).

A map feature which has no entry in this file is considered to be unlabeled. This means that during the vector to raster conversion (i.e., *vect.to.cell*), unlabeled areas will convert as category zero, and unlabeled lines will be ignored.

[9] This can be written with the Fortan format: *A1,1X,I4*.

[10] These can be written with the Fortran format: *2(1X,F12.2)*.

The format of this file is rather strict, and is described in the following table:

columns	data
1	Type of map feature (*A* or *L*)*
2-3	spaces
4-15	Easting (x) of the marker, right justified
16-17	spaces
18-29	Northing (y) of the marker, right justified
30-31	spaces
32-39	Category number, right justified
40-49	spaces
50	newline †

This format is required by programs which modify the vector map (e.g., *digit*). Programs which only read the vector map accept a looser format: the feature type must start in column 1; the items must be separated by at least one space; and the entries must be less than 50 characters. Also, the program *support.vect* will convert the looser format to this stricter format.

Note. The marker is specified as **x,y** (i.e., east, north), which is the way GRASS usually represents geographic coordinates, but which is reverse of the way the arcs are stored in the *dig_ascii* file.

6.4. Vector Category Label File

Each category in the vector map layer may have a one-line description. These category labels are stored in the *dig_cats* file. The format of this file is identical to the grid cell category file described in §*5.4 Cell Category File Format* [*p.28*], and the reader is referred to that section for details.

Note. The program *support.vect* allows the user to enter and modify the vector category labels. The program *vect.to.cell* copies the *dig_cats* file to the cell category file during the vector to raster conversion.

Note. Library routines which read and write the *dig_cats* file are described under §*12.10.6 Vector Category File* [*p.104*].

* Other types, such as *point*, may be allowed in the future.

† UNIX text files are terminated with a newline. Therefore, each entry will appear as 49 characters. The entire file size should be a multiple of 50.

6.5. Vector In[illegible] and Pointer File

The *dig_plus* file contains information that accelerates vector queries. It is created by the program *build.vect* (which is run by *digit* when a vector file is created or modified, and by *support.vect* at user request) from the data in the *dig* and *dig_att* files.

For this reason, and since the internal structure of the *dig_plus* file is complex, the format of this file will not be described.

6.6. Digitizer Registration Points File

The *reg* file is an ascii file used by the *digit* program to store map registration control points. Each map registration point has one entry with the easting and northing of the map control point. For example:

```
383000.000000   4429000.000000
383000.000000   4456000.000000
404000.000000   4456000.000000
404000.000000   4429000.000000
```

Note. This file is used by *digit* only. It is *not* used by any other program in GRASS.

6.7. Vector Topology Rules

The following rules apply to the vector data:

1 Arcs should not cross each other (i.e., arcs which would cross must be split at their intersection to form distinct arcs).

2 Arcs which share nodes must end at exactly the same points (i.e., must be *snapped* together). This is particularly important since nodes are not explicitly represented in the arc file, but only implicitly as endpoints of arcs.

3 Common boundaries should appear only once (i.e., should not be double digitized).

4 Areas must be explictly closed. This means that it must be possible to complete each area by following one or more area edges that are connected by common nodes, and that such tracings result in closed areas.

5 It is recommended that area features and linear features be placed in separate layers. However if area features and linear features must appear in one layer, common boundaries should be digitized only once. An area edge that is also a line (e.g., a road which is also a field boundary), should be digitized as an area edge (i.e., arc type A) to complete the area. The area feature should be labeled as an area (i.e., feature type A in the *dig_att* file). Additionally, the common boundary arc itself (i.e., the area edge which is also a line) should be labeled as a line (i.e., feature type L in the *dig_att* file) to identify it as a linear feature.

6.8. Importing Vector Files Into GRASS

The following files are required or recommended for importing vector files from other systems into GRASS:

dig_ascii

The *dig_ascii* file, described in §*6.2 Ascii Arc File Format* [p.32], is required.

dig_att

The *dig_att* file, described in §*6.3 Vector Category Attribute File* [p.35], is essentially required. While the *dig_ascii* file alone is sufficient for simple vector display, the *dig_att* file is required for vector to cell conversion, as well as more sophisticated vector query.

dig_cats

The *dig_cats* file, described in §*6.4 Vector Category Label File* [p.36], while not required, allows map feature descriptions to be imported as well.

Note. The *dig_plus* file, described in §*6.5 Vector Index and Pointer File* [p.37], is created by the GRASS program *import.to.vect* when converting the *dig_ascii* file to the binary *dig* file.

Chapter 7

Point Data: Site List Files

This section describes how point data is currently accommodated in the GRASS database.

7.1. What is a Site List?

Point data is currently stored in ascii files called *site lists* or *site files*. These files are used by the *sites*[1] program, which was developed as an application within GRASS to aid in archeological site predictive modeling. The *site list* files were designed for use by this program, but have since become the principal data structure for point data.[2]

7.2. Site File Format

Site files are ascii files stored under the **site_lists** database element.[3] The format of a site file is best explained by example:

```
name|sample
desc|sample site list
728220|5182440|site 27
727060|5181710|site 28
725500|5184000|site 29
719800|5187200|site 30
```

name

This line contains the name of the site list file, and is printed on all the reports generated by the *sites* program. The word **name** must be all lower case letters.

It is permissible for this line to be missing, since the *sites* program will add a name record using the name of the site list file itself.

[1] The *GRASS User's Reference Manual, 1988* contains a complete description of the *sites* capability.

[2] Other GRASS programs which read site lists include *Gsites, d.sites* and *paint*.

[3] See §*4.5.2 Elements* [*p. 18*] for an explanation of database elements.

desc

This line contains a description of the site list file, and is printed on all the reports generated by the *sites* program. The word **desc** must be all lower case letters.

It is also permissible for this line to be missing, in which case the site list will have no description.

points

The remaining lines are *point* records. Each site is described by a *point* record. The format for this record is:

```
east|north|description
```

The *east* and *north* fields represent the geographic coordinates (easting and northing) of the site. The *description* field provides a one line text description (label) of the site, and is optional.

comments

Blank lines, and lines beginning with #, are accepted (and ignored).

Note. The character | is used to separate the fields in the records.

7.3. Programming Interface to Site Files

The programming interface to the site list files is described in §*12.11 Site List Processing* [*p. 105*] and the programmer should refer to that section for details.

Chapter 8

Image Data: Groups

This chapter provides an explanation of how imagery data are accommodated in the GRASS database.

8.1. Introduction

Remotely sensed images are captured for computer processing by satellite or airborne sensors by filtering radiation emanating from the image into various electromagnetic wavelength bands, converting the overall intensity for each band to digital format, and storing the values on computer compatible media such as magnetic tape. Color and color infra-red photographs are optically scanned to convert the red, green, and blue wavelength bands in the photograph into a digital format as well.

The digitial format used by image data is basically a raster format. GRASS imagery programs[1] which extract image data from magnetic tape extract the band data into cell files in a GRASS database. Each band becomes a separate cell file, with standard GRASS data layer support, and can be displayed and analyzed just like any other cell file.

However, since the band files are extracted as individual cell files, it is necessary to have a mechanism to maintain a relationship between band files from the same image as well as cell files derived from the band files. The GRASS *group* database structure accomplishes this goal.

8.2. What is a Group?

The group is a database mechanism which provides the following:

(1) A list of related cell files.

(2) A place to store control points for image registration and rectification, and

[1] See §8.4 *Imagery Programs* [p. 45] for a list of the major GRASS imagery programs.

(3) A place to store spectral signatures, image statistics, etc., which are needed by image classification proceedures.

8.2.1. A List of Cell Files

The essential feature of a group is that it has a list of cell files that belong in the group. These can be band data extracted from the same data tape, or cell files derived from the original band files.[2] Therefore, the group provides a convenient "handle" for related image data; i.e., referring to the *group* is equivalent to referring to all the band files at once.

8.2.2. Image Registration and Rectification

The group also provides a database mechanism for image registration and rectification. The band data extracted from tapes are usually unregistered data. This means that the GRASS software does not know the Earth coordinates for pixels in the image. The only coordinates known at the time of extraction are the columns and the rows relative to the way the data was stored on the tape.

Image *registration* is the process of associating Earth coordinates with pixels on the image. Image *rectification* is the process of converting the image files to the new coordinate system based on the registration.

Image registration is applied to a group, rather than to individual cell files. The user displays any of the cell files in a group on the graphics monitor and then marks control points on the image, assigning Earth coordinates to each control point. The control points are stored in the group, allowing all related group files to be registered in one step rather than individually.

Image rectification is applied to individual cell files, with the control points for the group used to control the rectification. The rectified cell files are placed into another database[3] known as the *target* database. Rectification can be applied to any or all of the cell files associated with a group.

8.2.3. Image Classification

Image classification methods process all or a subset of the band files as a unit. For example, a clustering algorithm generates spectral signatures which are then used by a maximum likelihood classifier to produce a landcover map.

[2] Derived cell files can be the results of image classification procedures such as clustering and maximum likelihood, or band ratios formed using *Gmapcalc*, etc.

[3] Either a projected database, such as UTM, or an unregistered database, if the image is being registered to another image.

Sometimes only a subset of the band files are used during image classification. The signatures must be associated only with the cell files actually used in the analysis. Therefore, within a group, *subgroups* can be formed which list only the band files to be "subgrouped" for classification purposes. The signatures are stored with the subgroup. Multiple subgroups can be created within a group, which allows different classifications to be run with different combinations of band files.

8.3. The Group Structure

Groups live in the GRASS database under the **group** database element.[4] The structure of a group can be seen in the following diagram. A trailing / indicates a directory.

```
                          group/
                            |
      ------------------------------------------------------
      |            |              |              |         |
  mss.may80/   nhap.jun88/   nhap.oct88/    tm.apr88/     ...

                         tm.apr88/
                            |
              ------------------------------------
              |         |           |           |
             REF     POINTS      TARGET     subgroup/
```

In this example, the groups are named *mss.may80*, *nhap.jun88*, etc.[5] Note that each group is itself a directory. Each group contains some files (*REF*, *POINTS*, and *TARGET*), and a subdirectory (*subgroup*).

8.3.1. The REF File

The REF file contains the list of cell files associated with the group. The format is illustrated below:

```
tm.apr88.1   grass
tm.apr88.2   grass
tm.apr88.3   grass
tm.apr88.4   grass
tm.apr88.5   grass
tm.apr88.7   grass
```

Each line of this file contains the name and mapset of a cell file. In this case, there are six cell files in the group: *tm.apr88.1*, *tm.apr88.2*, *tm.apr88.3*, *tm.apr88.4*, *tm.apr88.5* and *tm.apr88.7* in mapset *grass*. (Presumably these are bands 1-5 and 7 from an April 88 Landsat Thematic Mapper image.)

[4] See §*4.5.2 Elements* [p. 18] for an explanation of database elements.

[5] The group names are chosen by the user.

8.3.2. The POINTS File

The POINTS file contains the image registration control points. This file is created and modfied by the *i.points* program. Its format is illustrated below:

```
#          image                    target              status
#    east       north        east         north        (1=ok)
#
     504.00    -2705.00    379145.30    4448504.56       1
     458.00    -2713.00    378272.67    4448511.67       1
    2285.80    -2296.00    415610.08    4450456.17       1
    2397.00    -2564.00    417043.22    4444757.65       0
    2158.00    -2944.00    411037.79    4438210.97       1
    2148.00    -2913.00    410834.61    4438656.18       0
    2288.80    -2336.20    415497.19    4449671.77       1
```

The lines which begin with # are comment lines. The first two columns of data (under *image*) are the column (i.e., *east*) and row (i.e., *north*[6]) of the registration control points as marked on the image. The next two columns (under *target*) are the *east* and *north* of the marked points in the target database coordinate system (in this case, a UTM database). The last column (under *status*) indicates whether or not the control point is well placed.[7] (If it is ok, then it will be used as a valid registration point. Otherwise, it is simply retained in the file, but not used.)

8.3.3. The TARGET File

The TARGET file contains the name of the *target* database; i.e., the GRASS database mapset into which rectified cell files will be created. The TARGET file is written by *i.target* and has two lines:

```
spearfish
grass
```

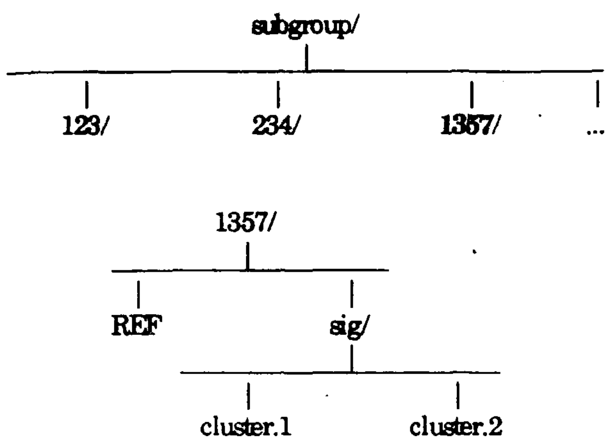
The first line is the GRASS location (in this case *spearfish*), and the second is a mapset within the location (in this case *grass*).

8.3.4. Subgroups

The subgroup directory under a group has the following structure:

[6] Note that the row values are negative. This is because GRASS requires the northings to *increase* from south to north. Negative values accomplish this while preserving the row value. The true image row is the absolute value.

[7] The user makes this decision in *i.points*.



In this example, the subgroups are named *123*, *234*, *1357*, etc.[8] Within each subgroup, there is a REF file and a *sig* directory. The REF file would list a subset of the cell files from the group. In this example, it could look like:

```
tm.apr88.1   grass
tm.apr88.3   grass
tm.apr88.5   grass
tm.apr88.7   grass
```

indicating that the subgroup is composed of bands 1, 3, 5, and 7 from the April 1988 TM scene. The files *cluster.1* and *cluster.2*[9] under the *sig* directory contain *spectral signature* information (i.e., statistics) for this combination of band files. The files were generated by different runs of the clustering program *i.cluster*.

8.4. Imagery Programs

The following is a list of some of the imagery programs in GRASS, with a brief description of what they do. Refer to the *GRASS User's Reference Manual* for more details.

[8] The subgroup names are chosen by the user (hopefully reflecting the contents of the subgroup).

[9] Again, these file names are chosen by the user.

image extraction

i.tape.mss	Landsat Multi-Spectral Scanner data
i.tape.tm	Landsat Thematic Mapper data
i.tape.other	other formats, such as scanned aerial photography or SPOT satellite data

image rectification

i.points	image registration (assign control points)
i.rectify	image rectification
i.target	establish target database for the group

image classification

i.cluster	unsupervised clustering
i.maxlik	maximum likelihood classifier

other

i.group	group management

8.5. Programming Interface for Groups

The programming interface to the group data is described in §*14 Imagery Library* [*p. 137*] and the reader is referred to that chapter for details.

Chapter 9

Window and Mask

GRASS users are provided with two mechanisms for specifying the area of the earth in which to view and analyze their data. These are known in GRASS as the *window* and the *mask*. The user is allowed to set a *window* which defines a rectangular area of coverage on the earth, and optionally further limit the coverage by specifying a "cookie-cutter" *mask*. The window and mask are stored in the database under the user's current mapset. GRASS programs automatically retrieve only data that fall within the window. Furthermore, if there is a mask, only data that fall within the mask are retained. Programs determine the window and mask from the database rather than asking the user.

9.1. Window

The user's current database window[1] is set by the user using the GRASS *window, Gwindow,* or *d.window* commands. It is stored in the WIND file in the mapset. This file not only specifies the geographic boundaries of the window rectangle, but also the window resolution which implicitly grids the window into rectangular "cells" of equal size.

Users expect map layers to be resampled into the current window. This implies that map layers must be extended with no data for portions of the window which do not cover the map layer, and that the map layer data be resampled to the window resolution if the cell file resolution is different. Users also expect new map layers to be created with exactly the same boundaries and resolution as the current window.

[1] The choice of the term "window" is unfortunate. It is used in other contexts as well (e.g., graphics windows) leading to much user confusion. A better term would have been "coverage." When confusion arises, refer to this window as the "database window" or the "mapset window", and to windows on the graphics screen as "graphics windows."

The WIND file contains the following fields:

WIND

north:	4660000.00
south:	4570000.00
east:	770000.00
west:	710000.00
e-w resol:	50.00
n-s resol:	100.00
proj:	1
zone:	18

north, south, east, west

The geographic boundaries of the window are given by the *north, south, east,* and *west* fields. Note: these values describe the lines which bound the window at its edges. These lines do NOT pass through the center of the grid cells which form the window edge, but rather along the edge of the window itself.

e-w resol, n-s resol

The fields *e-w resol* and *n-s resol* (which stand for east-west resolution and north-south resolution respectively) describe the size of each grid cell in the window in physical measurement units (e.g., meters in a UTM database). The *e-w resol* is the length of a grid cell from east to west. The *n-s resol* is the length of a grid cell from north to south. Note that since the *e-w resol* may differ from the *n-s resol,* window grid cells need not be square.

proj, zone

The *proj*ection field specifies the type of cartographic projection: 0 is unreferenced x,y (imagery data), 1 is UTM, 2 is State Plane.[2] Others may be added in the future. The *zone* field is the projection zone. In the example above, the projection is UTM, the zone 18.

Note. The WIND file format is very similar to the format for the cell header files. See *§5.3 Cell Header Format* [p.26] for details about cell header files.

9.2. Mask

In addition to the window, the user may set a mask using the *mask* command. The mask is stored in the user's current mapset as a cell file with the name MASK.[3] The mask acts like an opaque filter when reading other cell files. No-data cells in the mask (i.e., category zero) will cause corresponding cells in other cell files to be read as no data (irrespective of the actual value in the cell file).

[2] State Plane is not yet fully supported in GRASS.

[3] The *mask* program creates MASK as a reclass file because the reclass function is fast and uses less disk space, but it doesn't actually matter that MASK is a reclass file. Any cell format can be used. The only thing that really matters is that the cell file be called MASK.

The following diagram gives a visual idea of how the mask works:

$$\begin{array}{ccccc} \text{input} & & \text{MASK} & & \text{output} \\ \begin{array}{|c|c|c|}\hline 3 & 4 & 4 \\ \hline 3 & 3 & 4 \\ \hline 2 & 3 & 3 \\ \hline \end{array} & + & \begin{array}{|c|c|c|}\hline 0 & 1 & 1 \\ \hline 1 & 1 & 0 \\ \hline 1 & 0 & 0 \\ \hline \end{array} & = & \begin{array}{|c|c|c|}\hline 0 & 4 & 4 \\ \hline 3 & 3 & 0 \\ \hline 2 & 0 & 0 \\ \hline \end{array} \end{array}$$

9.3. Variations

If a GRASS program does not obey either the *window* or the *mask*, the variation must be noted in the user documentation for the program, and the reason for the variation given. For example, the *slope.aspect* program which generates aspect and slope maps from elevation data uses the resolution of the elevation data itself, and not the current window resolution (which may differ). The program documentation for *slope.aspect* warns the user about this: *The current window and mask settings are ignored. The elevation file is read directly to insure that data is not lost or inappropriately resampled.*

Chapter 10

Environment Variables

GRASS programs are written to be independent of which database the user is using, where the database resides on the disk, or where the programs themselves reside. When programs need this information, they get some of it from UNIX environment variables, and the rest from GRASS environment variables.

10.1. UNIX Environment

The GRASS start-up commands *GRASS3* and *grass3* set the following UNIX environment variables:[1]

GISBASE	top level directory for the GRASS programs
GIS_LOCK	process id of the start-up shell script
GISRC	name of the GRASS environment file

GISBASE is the top level directory for the GRASS programs. For example, if GRASS were installed under */grass*, then GISBASE would be set to */grass*. The command directory would be */grass/bin*, the command support directory would be */grass/etc*, the source code directory would be */grass/src*, the on-line manual would live in */grass/man*, the menu files would be found in */grass/menu*, etc.

GISBASE, while set in the UNIX environment, is given special handling in GRASS code. This variable must be accessed using the *GIS Library* routine *G_gisbase*(*p.66*).

GIS_LOCK is used for various locking mechanisms in GRASS. It is set to the process id of the start-up shell so that locking mechanisms can detect orphaned locks (e.g., locks that were left behind during a system crash).

GIS_LOCK may be accessed using the UNIX getenv( ) routine.

GISRC is set to the name of the GRASS environment file where all other GRASS

[1] Any interface to GRASS must set these variables.

variables are stored. Under GRASS 3.0 this file is **.grassrc**[2] in the user's home directory.

10.2. GRASS Environment

All GRASS users will have a file in their home directory named **.grassrc**[3] which is used to store the variables that comprise the environment of all GRASS programs. This file will always include the following variables that define the database in which the user is working:

GISDBASE	top level database directory
LOCATION_NAME	location directory
MAPSET	mapset directory

The user sets these variables during GRASS start-up. While the value of GISDBASE will be relatively constant, the others may change each time the user runs GRASS. GRASS programs access these variables using the *G_gisdbase*(*p. 67*), *G_location*(*p. 66*), and *G_mapset*(*p. 66*) routines in the *GIS Library*. See §*4.2 Gisdbase* [*p. 16*] for details about GISDBASE, §*4.3 Locations* [*p. 16*] for details about database locations, and §*4.4 Mapsets* [*p. 16*] for details about mapsets.

Other variables may appear in this file. Some of these are:

MONITOR	currently selected graphics monitor
PAINTER	currently selected paint output device
DIGITIZER	currently selected digitizer

These variables are accessed and set from C programs using the general purpose routines *G_getenv*(*p. 67*) and *G_setenv*(*p. 67*). The GRASS program *gisenv* provides a command level interface to these variables.

10.3. Difference Between GRASS and UNIX Environments

The GRASS environment is similar to the UNIX environment in that programs can access information stored in "environment" variables. However, since the GRASS environment variables are stored in a disk file, it offers two capabilities not available

[2] Under previous versions of GRASS this file was named .gisrc

[3] GRASS programs do not have this file name built into them. They look it up from the UNIX environment variable GISRC. Note the similarity in naming convention to the .cshrc and .exrc files.

with UNIX environment variables. First, variables may be set by one program for later use by other programs. For example, the GRASS start-up sets these variables for use by all other GRASS application programs. Second, since the variables remain in the file unless explicitly removed, they are available from session to session.

Chapter 11

Compiling GRASS Programs Using Gmake

GRASS programs are compiled using the *Gmake* front-end to the UNIX *make* command. *Gmake* reads a file named *Gmakefile* to construct a *makefile* and then runs *make*. (It is assumed that the programmer is familiar with *make* and its accompanying *makefiles*.)

11.1. Gmake

The GRASS *Gmake* utility allows *make* compilation rules to be developed without having to specify machine- and installation-dependent information. *Gmake* combines pre-defined variables that specify the machine- and installation-dependent information with the file *Gmakefile,* which the programmer must write, to create a *makefile*. (The pre-defined variables and the construction of a *Gmakefile* are described below.)

Gmake is invoked as follows:[1]

```
Gmake [source directory] [target]
```

If run without arguments, *Gmake* will run in the current directory, build a *makefile* from the *Gmakefile* found there, and then run *make*. If run with a source directory argument, *Gmake* will change into this directory and then proceed as above. If run with a target argument as well, then *make* will be run on the specified target.

11.2. Gmake Variables

The pre-defined *Gmake* variables which the GRASS programmer must use when writing a *Gmakefile* specify libraries, source and binary directories, compiler and loader flags, etc. The most commonly used variables will be defined here. Examples of how to use them follow in §*11.3 Constructing a Gmakefile* [p. 58]. The full set of variables can be seen in *Appendix A. Annotated Gmake Pre-defined Variables* [p. 233].

[1] *Gmake* lives under $GISBASE/src/CMD. You must either set your $PATH to include this directory, or run $GISBASE/src/CMD/Gmake. $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [p. 51] for details.

Variables marked with (-) are not commonly used.

GRASS Directories. The following variables tell *Gmake* where source code and program directories are:

GIS (-)	This is the UNIX directory where GRASS is installed. It corresponds to the GRASS environment variable GISBASE (see §*10 Environment Variables* [*p. 51*]). This variable is generally not used explicitly in a *Gmakefile*. It is mostly used by *Gmake* to construct other variables.
SRC (-)	This is the directory where GRASS source code lives.
BIN	This is the directory where user-accessible GRASS programs live.
ETC	This is the directory where support files and programs live. These support files and programs are used by the $(BIN) programs, and are not known to, or run by the user.
LIBDIR (-)	This is the directory where most of the GRASS libraries and include header files live. For example, "gis.h" can be found here. *Gmake* automatically specifies this directory to the C compiler as a place to find include files.

GRASS Libraries. The following variables name the various GRASS libraries:

GISLIB	This names the *GIS Library,* which is the principal GRASS library. See §*12 GIS Library* [*p. 63*] for details about this library, and §*12.18 Loading the GIS Library* [*p. 122*] for a sample *Gmakefile* which loads this library.
VASKLIB	This names the *Vask Library,* which does full screen user input.
VASK	This specifies the *Vask Library* plus the UNIX curses and termcap libraries needed to use the *Vask Library* routines. See §*20 Vask Library* [*p. 187*] for details about this library, and §*20.4 Loading the Vask Library* [*p. 191*] for a sample *Gmakefile* which loads this library.
SEGMENTLIB	This names the *Segment Library,* which manages large matrix data. See §*19 Segment Library* [*p. 179*] for details about this library, and §*20.4 Loading the Vask Library* [*p. 191*] for a sample *Gmakefile* which loads this library.
RASTERLIB	This names the *Raster Graphics Library,* which communicates with GRASS graphics drivers. See §*15 Raster Graphics Library* [*p. 147*] for

details about this library, and §*15.9 Loading the Raster Graphics Library* [*p. 157*] for a sample *Gmakefile* which loads this library.

DISPLAYLIB
: This names the *Display Graphics Library,* which provides a higher level graphics interface to $(RASTERLIB). See §*16 Display Graphics Library* [*p. 159*] for details about this library, and §*16.9 Loading the Display Graphics Library* [*p. 167*] for a sample *Gmakefile* which loads this library.

UNIX Libraries. The following variables name some useful UNIX system libraries:

MATHLIB This names the math library. It should be used instead of the -lm loader option.

CURSES This names both the curses and termcap libraries. It should be used instead of the -lcurses and -ltermcap loader options. Don't use $(CURSES) if you use $(VASK).

TERMLIB This names the termcap library. It should be used instead of the -ltermcap or -ltermlib loader options. Don't use $(TERMLIB) if you use $(VASK) or $(CURSES).

Compiler and loader variables. The following variables are related to compiling and loading C programs:

AR This variable specifies the rule that must be used to build object libraries.

CFLAGS (-)
: This variable specifies all the C compiler options. It should never be necessary to use this variable. *Gmake* automatically supplies this variable to the C compiler.

EXTRA_CFLAGS
: This variable can be used to add additional options to $(CFLAGS). It has no pre-defined values. It is usually used to specify additional -I include directories, or -D pre-processor defines.

GMAKE This is the full name of the *Gmake* command. It can be used to drive compilation in subdirectories.

LDFLAGS This specifies the loader flags. The programmer must use this variable when loading GRASS programs since there is no way to automatically supply these flags to the loader.

MAKEALL

This defines a command which runs *Gmake* in all subdirectories that have a *Gmakefile* in them.

11.3. Constructing a Gmakefile

A *Gmakefile* is constructed like a *makefile*. The complete syntax for a *makefile* is discussed in the UNIX documentation for *make* and won't be repeated here. The essential idea is that a target (e.g., a GRASS program) is to be built from a list of dependencies (e.g., object files, libraries, etc.). The relationship between the target, its dependencies, and the rules for constructing the target is expressed according to the following syntax:

```
target: depedencies
	actions
	more actions
```

If the target doesn't exist, or if any of the dependencies have a newer date than the target (i.e., have changed), the actions will be executed to build the target.

The actions must be indented using a TAB. *Make* is picky about this. It doesn't like spaces in place of the TAB.

11.3.1. Building programs from source (.c) files

To build a program from C source code files, it is only necessary to specify the compiled object (.o) files as dependencies for the target program, and then specify an action to load the object files together to form the program. The *make* utility builds .o files from .c files without being instructed to do so.

For example, the following *Gmakefile* builds the program *xyz* and puts it in the GRASS program directory.

```
OBJ = main.o sub1.o sub2.o sub3.o

$(BIN)/xyz: $(OBJ) $(GISLIB)
	$(CC) $(LDFLAGS) -o $@ $(OBJ) $(GISLIB)

$(GISLIB): # in case library changes
```

The target *xyz* depends on the object files listed in the variable $(OBJ) and the $(GISLIB) library. The action runs the C compiler to load xyz from the $(OBJ) files and $(GISLIB).

$@ is a *make* shorthand which stands for the target, in this case *xyz*. Its use should be encouraged, since the target name can be changed without having to edit the action as well.

$(CC) is the C compiler. It is used as the interface to the loader. It should be specified as $(CC) instead of cc. *Make* defines $(CC) as cc, but using $(CC) will allow other C-like compilers to be used instead.[2]

$(BIN) is a *Gmake* variable which names the UNIX directory where GRASS commands live. Specifying the target as $(BIN)/xyz will cause *Gmake* to build *xyz* directly into the $(BIN) directory.

$(LDFLAGS) specify loader flags which must be passed to the loader in this manner.

$(GISLIB) is the *GIS Library*. $(GISLIB) is specified on the action line so that it is included during the load step. It is also specified in the dependency list so that changes in $(GISLIB) will also cause the program to be reloaded.

Note that no rules were given for building the .o files from their related .c files. In fact, the GRASS programmer should almost never have to give an explicit rule for compiling .c files. It is sufficient to list all the .o files as dependencies of the target. The .c files will be automatically compiled to build up-to-date .o files before the .o files are loaded to build the target program.

Also note that since $(GISLIB) is specified as a dependency it must also be specified as a target. *Make* must be told how to build all dependencies as well as targets. In this case a dummy rule is given to satisfy *make*.

11.3.2. Include files

Often C code uses the #include directive to include header files in the source during compilation. Header files that are included into C source code should be specified as dependencies as well. It is the .o files which depend on them:

```
OBJ = main.o sub1.o sub2.o

$(BIN)/xyz: $(OBJ) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(GISLIB)

$(OBJ): myheader.h

$(GISLIB): # in case library changes
```

[2] GRASS *Gmakefiles* presently use cc instead of $(CC). This will be modified in future releases.

In this case, it is assumed that "myheader.h" lives in the current directory and is included in each source code file. If "myheader.h" changes, then all .c files will be compiled even though they may not have changed. And then the target program *xyz* will be reloaded.

If the header file "myheader.h" is in a different directory, then a different formulation can be used:

```
EXTRA_CFLAGS = -I..
OBJ = main.o sub1.o sub2.o

$(BIN)/xyz: $(OBJ) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(GISLIB)

$(GISLIB): # in case library changes
```

$(EXTRA_CFLAGS) will add the flag -I.. to the rules that compile .c files into .o files. This flag indicates that #include files (i.e., "myheader.h") can also be found in the parent (..) directory.

Note that this example does not specify that "myheader.h" is a dependency. If "myheader.h" were to change, this would not cause recompilation here. The following rule could be added:

```
$(OBJ): ../myheader.h
```

11.3.3. Builing object libraries

Sometimes it is desirable to build libraries of subroutines which can be used in many programs. *Gmake* requires that these libraries be built using the $(AR) rule as follows:

```
OBJ = sub1.o sub2.o sub3.o

lib.a: $(OBJ)
    $(AR)
```

All the object files listed in $(OBJ) will be compiled and archived into the target library *lib.a*. The $(OBJ) variable must be used. The $(AR) assumes that all object files are listed in $(OBJ).

11.3.4. Building more than one target

Many *target : dependency* lines many be given. However, it is the first one in the *Gmakefile* which is built by *Gmake*. If there are more targets to be built, the first target must explicity or implicitly cause *Gmake* to build the others.

The following builds two programs, *abc* and *xyz* directly into the $(BIN) directory:

```
ABC = abc.o sub1.o sub2.o
XYZ = xyz.o sub1.o sub3.o

all: $(BIN)/abc $(BIN)/xyz

$(BIN)/abc: $(ABC) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(ABC) $(GISLIB)

$(BIN)/xyz: $(XYZ) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(ABC) $(GISLIB)

$(GISLIB): # in case library changes
```

If it is desired to run the compilation in various subdirectories, a *Gmakefile* could be constructed which simply runs *Gmake* in each subdirectory. For example:

```
all:
    $(GMAKE) subdir.1
    $(GMAKE) subdir.2
    $(GMAKE) subdir.3
```

Note that due to the way the $(AR) rule is designed, it is not possible to construct more than one library in a single source code directory. Each library must have its own directory and related *Gmakefile*.

11.3.5. Don't bypass .o files

If a program has only one .c source file, it is tempting to compile the program directly from the .c file without creating the .o file. Please don't do this. There have been problems on some systems specifying both compiler and loader flags at the same time. The .o files must be built first. Once all the .o files are built, they are loaded with any required libraries to build the program.

Chapter 12

GIS Library

12.1. Introduction

The *GIS Library* is the primary programming library provided with the GRASS system. **Programs must use this libary to access the database.** It contains the routines which locate, create, open, rename, and remove GRASS database files. It contains the routines which read and write cell files. It contains routines which interface the user to the database, including prompting the user, listing available files, validating user access, etc. It also has some general purpose routines (string manipulation, user information, etc.) which are not tied directly to database processing.

It is assumed that the reader has read §4 *Database Structure* [p. 15] for a general description of GRASS databases, §5 *Grid Cell Maps* [p. 23] for details about map layers in GRASS, and §9 *Window and Mask* [p. 47] which discusses windowing and masking.

The routines in the *GIS Library* are presented in functional groupings, rather than in alphabetical order. The order of presentation will, it is hoped, provide a better understanding of how the library is to be used, as well as show the inter-relationships among the various routines. Note that a good way to understand how to use these routines is to look at the source code for GRASS programs which use them.

Most routines in this library require that the header file "gis.h" be included in any code using these routines.[1] Therefore, programmers should always include this file when writing code using routines from this library:

```
        #include "gis.h"
```

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **G_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix C. Index to GIS Library* [p. 239].

[1] The GRASS compilation process, described in §*11 Compiling GRASS Programs Using Gmake* [p. 55], automatically tells the C compiler how to find this and other GRASS header files.

12.2. Library Initialization

It is **mandatory** that the system be initialized before any other library routines are called.

G_gisinit (program_name) *initialize gis library*

    char *program_name;

This routine reads the user's GRASS environment file into memory and makes sure that the user has selected a valid database and mapset. It also initializes hidden variables used by other routines. If the user's database information is invalid, an error message is printed and the program exits. The **program_name** is stored for later recall by *G_program_name(p.118)*. It is recommended that argv[0] be used for the **program_name**:

```
main(argc, argv) char *argv[ ];
{
        G_gisinit(argv[0]);
}
```

12.3. Diagnostic Messages

The following routines are used by other routines in the library to report warning and error messages. They may also be used directly by GRASS programs.

G_fatal_error (message) *print error message and exit*

G_warning (message) *print warning message and continue*

    char *message;

These routines report errors to the user. The normal mode is to write the **message** to the screen (on the standard error output) and wait a few seconds. G_warning( ) will return and G_fatal_error( ) will exit.

If the standard error output is not a tty device, then the message is mailed to the user instead.

If the file GIS_ERROR_LOG exists (with write permission), in either the user's home directory or in the $GISBASE[2] directory, the messages will also be logged to this file.

While most applications will find the normal error reporting quite adequate, there will be times when different handling is needed. For example, graphics programs may

[2] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* *(p.51)* for details.

want the messages displayed graphically instead of on the standard error output. If the programmer wants to handle the error messages differently, the following routines can be used to modify the error handling:

G_set_error_routine (handler) *change error handling*

```
int (*handler)( );
```

This routine provides a different error handler for G_fatal_error( ) and G_warning( ). The **handler** routine must be defined as follows:

```
handler (message, fatal)
        char *message;
        int fatal;
```

where **message** is the message to be handled and **fatal** indicates the type of error: 1 (fatal error) or 0 (warning).

Note. The handler only provides a way to send the message somewhere other than to the error output. If the error is fatal, the program will exit after the handler returns.

G_unset_error_routine ( ) *reset normal error handling*

This routine resets the error handling for *G_fatal_error*(*p. 64*) and *G_warning*(*p. 64*) back to the default action.

G_sleep_on_error (flag) *sleep on error?*

```
int flag;
```

If **flag** is 0, then no pause will occur after printing an error or warning message. Otherwise the pause will occur.

G_suppress_warnings (flag) *suppress warnings?*

```
int flag;
```

If **flag** is 0, then *G_warning*(*p. 64*) will no longer print warning messages. If **flag** is 1, then G_warning( ) will print warning messages.

Note. This routine has no effect on *G_fatal_error*(*p. 64*).

12.4. Environment and Database Information

The following routines return information about the current database selected by the user. Some of this information is retrieved from the user's GRASS environment file. Some of it comes from files in the database itself. See §*10 Environment Variables* [*p. 51*] for a discussion of the GRASS environment.

The following four routines can be used freely by the programmer:

char *
G_location ( ) *current location name*

Returns the name of the current database location. This routine should be used by programs that need to display the current location to the user. See §*4.3 Locations* [*p. 16*] for an explanation of locations.

char *
G_mapset ( ) *current mapset name*

Returns the name of the current mapset in the current location. This routine is often used when accessing files in the current mapset. See §*4.4 Mapsets* [*p. 16*] for an explanation of mapsets.

char *
G_myname ( ) *location title*

Returns a one line title for the database location. This title is read from the file MYNAME in the PERMANENT mapset. See also §*4.6 Permanent Mapset* [*p. 19*] for a discussion of the PERMANENT mapset.

char *
G_gisbase ( ) *top level program directory*

Returns the full path name of the top level directory for GRASS programs. This directory will have subdirectories which will contain programs and files required for the running of the system. Some of these directories are:

bin	commands run by the user
etc	programs and data files used by GRASS commands
txt	help files
menu	files used by the *grass3* menu interface

The use of G_gisbase( ) to find these subdirectories enables GRASS programs to be written independently of where the GRASS system is actually installed on the machine. For example, to run the program *sroff* in the GRASS *etc* directory:

```
char command[200];

sprintf (command, "%s/etc/sroff", G_gisbase( ) );
system (command);
```

The following two routines return full path UNIX directory names. They should be used only in special cases. They are used by other routines in the library to build full UNIX file names for database files. **The programmer should not use the next two routines to bypass the normal database access routines.**

char *
G_gisdbase ( ) *top level database directory*

Returns the full UNIX path name of the directory which holds the database locations. See §*4.2 Gisdbase* [*p. 16*] for a full explanation of this directory.

char *
G_location_path ( ) *current location directory*

Returns the full UNIX path name of the current database location. For example, if the user is working in location *spearfish* in the */usr/grass3/data* database directory, this routine will return a string which looks like */usr/grass3/data/spearfish.*

These next routines provide the low-level management of the information in the user's GRASS environment file. **They should not be used in place of the higher level interface routines described above.**

char *
G_getenv (name) *query GRASS environment variable*
char *
G__getenv (name) *query GRASS environment variable*

    char *name;

These routines look up the variable **name** in the GRASS environment and return its value (which is a character string).

If **name** is not set, G_getenv( ) issues an error message and calls exit( ). G_ setenv( ) just returns the NULL pointer.

G_setenv (name, value) *set GRASS environment variable*
G__setenv (name, value) *set GRASS environment variable*

    char *name;
    char *value;

These routines set the the GRASS environment variable **name** to **value.** If **value** is NULL, the **name** is unset.

Both routines set the value in program memory, but only G_setenv( ) writes the new value to the user's GRASS environment file.

12.5. Fundamental Database Access Routines

The routines described in this section provide the low-level interface to the GRASS database. They search the database for files, prompt the user for file names, open files for reading or writing, etc. The programmer should never bypass this level of database interface. **These routines must be used to access the GRASS database unless there are other higher level library routines which perform the same function.** For example, there are routines to process cell files which should be used instead (see *§12.8 Cell File Processing* [p.80]).

In the descriptions below, the term database *element* is used. Elements are subdirectories within a mapset and are associated with a specific GRASS data type. For example, cell files live in the "cell" element. See *§4.5.2 Elements* [p.18] for more details.

12.5.1. Prompting for Database Files

The following routines interactively prompt the user for a file name from a specific database **element**. (See *§4.5.2 Elements* [p.18] for an explanation of elements.) In each, the **prompt** string will be printed as the first line of the full prompt which asks the user to enter a file name. If **prompt** is the empty string "" then an appropriate prompt will be substituted. The name that the user enters is copied into the **name** buffer.[3] The short (one or two word) **label** describing the **element** is used as part of a title when listing the files in **element**.

The user is required to enter a valid file name, or else hit the RETURN key to cancel the request. If the user enters an invalid response, a message is printed, and the user is prompted again. If the user cancels the request, the NULL pointer is returned. Otherwise the mapset where the file lives or is to be created is returned. Both the name and the mapset are used in other routines to refer to the file.

An example will be given here. The G_ask_old( ) routine used in the example is described a bit later. The user is asked to enter a file from the "paint/labels" element:

```
char name[50];
char *mapset;

mapset = G_ask_old ("", name, "paint/labels", "labels");
if (mapset == NULL)
        exit(0);   /* user canceled the request */
```

The user will see the following:

[3] The size of **name** should be large enough to hold any GRASS file name. Most systems allow file names to be quite long. It is recommended that name be declared *char name[50]*.

```
Enter the name of an existing labels file
Enter 'list' for a list of existing labels files
Hit RETURN to cancel request[4]
>
```

char *
G_ask_old (prompt, name, element, label) *prompt for existing database file*

char *prompt;
char *name;
char *element;
char *label;

The user is asked to enter the name of an existing database file.

Note. This routine looks for the file in the current mapset as well as other mapsets. The mapsets that are searched are determined from the user's mapset search path. See §*4.7.1 Mapset Search Path* [p.20] for some more details about the search path.

char *
G_ask_new (prompt, name, element, label) *prompt for new database file*

char *prompt;
char *name;
char *element;
char *label;

The user is asked to enter the name of a new file which does not exist in the current mapset.

Note. The file chosen by the user may exist in other mapsets. This routine does not look in other mapsets, since the assumption is that **name** will be used to create a new file. New files are always created in the current mapset.

[4] This line of the prompt can be modified using *G_set_ask_return_msg* (p. 70).

char *
G_ask_in_mapset (prompt, name, element, label) *prompt for existing database file*

```
    char *prompt;
    char *name;
    char *element;
    char *label;
```

The user is asked to enter the name of an file which exists in the current mapset.

Note. The file chosen by the user may or may not exist in other mapsets. This routine does not look in other mapsets, since the assumption is that **name** will be used to modify a file. GRASS only permits users to modify files in the current mapset.

char *
G_ask_any (prompt, name, element, label, warn) *prompt for any valid file name*

```
    char *prompt;
    char *name;
    char *element;
    char *label;
    int warn;
```

The user is asked to enter any legal file name. If **warn** is 1 and the file chosen exists in the current mapset, then the user is asked if it is ok to overwrite the file. If **warn** is 0, then any legal name is accepted and no warning issued to the user if the file exists.

G_set_ask_return_msg (msg) *set Hit RETURN msg*

```
    char *msg;
```

The "Hit RETURN to cancel request" part of the prompt in the prompting routines described above, is modified to "Hit RETURN **msg**."

char *
G_get_ask_return_msg ( ) *get Hit RETURN msg*

The current *msg* (as set by *G_set_ask_return_msg*(*p. 70*)) is returned.

12.5.2. Finding Files in the Database

Non-interactive programs cannot make use of the interactive prompting routines described above. For example, a command line driven program may require a database file name as one of the command arguments. GRASS allows the user to specify database file names either as a simple unqualified name, such as "xyz", or as a fully qualified name, such as "xyz in *mapset*", where *mapset* is the mapset where the file is to be found. Often only the unqualified file name is provided on the command line.

The following routines search the database for files:

char *
G_find_file (element, name, mapset) *find a database file*

char *
G_find_file2 (element, name, mapset) *find a database file*

```
    char *element;
    char *name;
    char *mapset;
```

Look for the file **name** under the specified **element** in the database. The **mapset** parameter can either be the empty string "", which means search all the mapsets in the user's current mapset search path,[5] or it can be a specific mapset, which means look for the file only in this one mapset (for example, in the current mapset).

If found, the mapset where the file lives is returned. If not found, the NULL pointer is returned.

The difference between these two routines is that if the user specifies a fully qualified file which exists, then G_find_file2( ) modifies **name** by removing the "in *mapset*" while G_find_file( ) does not.[6] Normally, the GRASS programmer need not worry about qualified vs. unqualified names since all library routines handle both forms. However, if the programmer wants the name to be returned unqualified (for displaying the name to the user, or storing it in a data file, etc.), then G_find_file2( ) should be used.

For example, to find a "paint/labels" file anywhere in the database:

```
char name[50];
char *mapset;

if ((mapset = G_find_file("paint/labels",name,"")) == NULL)
        /* not found */
```

To check that the file exists in the current mapset:

[5] See §*4.7.1 Mapset Search Path* (p. 20) for more details about the search path.

[6] Be warned that G_find_file2( ) should not be used directly on a command line argument, since modifying argv[ ] may not be valid. The argument should be copied to another character buffer which is then passed to G_find_file2( ).

```
char name[50];

if (G_find_file("paint/labels",name,G_mapset()) == NULL)
        /* not found */
```

12.5.3. Legal File Names

Not all names that a user may enter will be legal files for the GRASS databases. The routines which create new files require that the new file have a legal name. The routines which prompt the user for file names (e.g., *G_ask_new(p.69)*) guarantee that the name entered by the user will be legal. If the name is obtained from the command line, for example, the programmer must check that the name is legal. The following routine checks for legal file names:

G_legal_filename (name) *check for legal database file names*

    char *name;

Returns 1 if **name** is ok, -1 if it isn't.

12.5.4. Opening an Existing Database File for Reading

The following routines open the file **name** in **mapset** from the specified **database element** for reading (but not for writing). The file **name** and **mapset** can be obtained interactively using *G_ask_old(p.69)*, and non-interactively using *G_find_file(p.71)* or *G_find_file2(p.71)*.

G_open_old (element, name, mapset) *open a database file for reading*

    char *element;
    char *name;
    char *mapset;

The database file **name** under the **element** in the specified **mapset** is opened for reading (but not for writing).

The UNIX open( ) routine is used to open the file. If the file doesn't exist, -1 is returned. Otherwise the file descriptor from the open( ) is returned.

FILE *
G_fopen_old (element, name, mapset) *open a database file for reading*

```
char *element;
char *name;
char *mapset;
```

The database file **name** under the **element** in the specified **mapset** is opened for reading (but not for writing).

The UNIX fopen( ) routine, with "r" read mode, is used to open the file. If the file doesn't exist, the NULL pointer is returned. Otherwise the file descriptor from the fopen( ) is returned.

12.5.5. Opening an Existing Database File for Update

The following routines open the file **name** in the current mapset from the specified database **element** for writing. The file must exist. Its **name** can be obtained interactively using *G_ask_in_mapset*(*p. 70*), and non-interactively using *G_find_file*(*p. 71*) or *G_find_file2*(*p. 71*).

G_open_update (element, name) *open a database file for update*

```
char *element;
char *name;
```

The database file **name** under the **element** in the current mapset is opened for reading and writing.

The UNIX open( ) routine is used to open the file. If the file doesn't exist, -1 is returned. Otherwise the file is positioned at the end of the file and the file descriptor from the open( ) is returned.

G_fopen_append (element, name) *open a database file for update*

```
char *element;
char *name;
```

The database file **name** under the **element** in the current mapset is opened for appending (but not for reading).

The UNIX fopen( ) routine, with "a" append mode, is used to open the file. If the file doesn't exist, the NULL pointer is returned. Otherwise the file is positioned at the end of the file and the file descriptor from the fopen( ) is returned.

12.5.6. Creating and Opening a New Database File

The following routines create the new file **name** in the current mapset[7] under the specified database **element** and open it for writing. The database **element** is created, if it doesn't already exist.

The file **name** should be obtained interactively using *G_ask_new*(*p. 69*). If obtained non-interactively (e.g., from the command line), *G_legal_filename*(*p. 72*) should be called first to make sure that **name** is a valid GRASS file name.

Warning. It is not an error for **name** to already exist. However, the file will be removed and recreated empty. The interactive routine *G_ask_new*(*p. 69*) guarantees that **name** will not exist, but if **name** is obtained from the command line, **name** may exist. In this case *G_find_file*(*p. 71*) could be used to see if **name** exists.

G_open_new (element, name) *open a new database file*

```
char *element;
char *name;
```

The database file **name** under the **element** in the current mapset is created and opened for writing (but not reading).

The UNIX open( ) routine is used to open the file. If the file doesn't exist, -1 is returned. Otherwise the file is positioned at the end of the file and the file descriptor from the open( ) is returned.

FILE *
G_fopen_new (element, name) *open a new database file*

```
char *element;
char *name;
```

The database file **name** under the **element** in the current mapset is created and opened for writing (but not reading).

The UNIX fopen( ) routine, with "w" write mode, is used to open the file. If the file doesn't exist, the NULL pointer is returned. Otherwise the file is positioned at the end of the file and the file descriptor from the fopen( ) is returned.

[7] GRASS doesn't allow files to be created outside the current mapset; see §4.7 *Database Access Rules* (*p. 20*).

12.5.7. Database File Management

The following routines allow the renaming and removal of database files in the current mapset.[8]

G_rename (element, old, new) *rename a database file*

```
char *element;
char *old;
char *new;
```

The file or directory **old** under the database **element** directory in the current mapset is renamed to **new.**

Returns 1 if successful, 0 if **old** doesn't exist, and -1 if there was an error.

Bug. This routine doesn't check to see if the **new** name is a valid database file name.

G_remove (element, name) *remove a database file*

```
char *element;
char *name;
```

The file or directory **name** under the database **element** directory in the current mapset is removed.

Returns 1 if successful, 0 if **name** doesn't exist, and -1 if there was an error.

Note. If **name** is a directory, everything within the directory is removed as well.

Note. These functions only apply to the specific **element** and not to other "related" elements. For example, if **element** is "cell", then the specified cell file will be remove (or renamed), but the other support files, such as "cellhd" or "cats", will not. To remove these other files as well, specific calls must be made for each related **element**.

12.6. Memory Allocation

The following routines provide memory allocation capability. They are simply calls to the UNIX suite of memory allocation routines malloc( ), realloc( ) and calloc( ), except that if there is not enough memory, they print a diagnostic message to that effect and then call exit( ).

Note. Use the UNIX free( ) routine to release memory allocated by these routines.

[8] These functions only apply to the current mapset since GRASS does permit users to modify things in mapsets other than the current mapset; see §4.7 *Database Access Rules* (p.20).

char *
G_malloc (size) *memory allocation*

    int size;

Allocates a block of memory at least **size** bytes which is aligned properly for all data types. A pointer to the aligned block is returned.

char *
G_realloc (ptr, size) *memory allocation*

    char *ptr;
    int size;

Changes the **size** of a previously allocated block of memory at **ptr** and returns a pointer to the new block of memory. The **size** may be larger or smaller than the original size. If the original block cannot be extended "in place", then a new block is allocated and the original block copied to the new block.

Note. If **ptr** is NULL, then this routine simply allocates a block of **size** bytes. This is different than malloc( ), which does not handle a NULL **ptr.**

char *
G_calloc (n, size) *memory allocation*

    int n;
    int size;

Allocates a properly aligned block of memory **n*size** bytes in length, initializes the allocated memory to zero, and returns a pointer to the allocated block of memory.

Note. Allocating memory for reading and writing cell files is discussed in §*12.8.5 Allocating Cell I/O Buffers* [*p. 85*]

12.7. The Window

The window concept is explained in §*9.1 Window* [*p. 47*]. It can be thought of as a two-dimensional matrix with known boundaries and rectangular cells.

There are logically two different windows. The first is the database window that the user has set in the current mapset. The other is the window that is active in the program. This active program window is what controls reading and writing of cell file data.

The routines described below use a GRASS data structure *Cell_head* to hold window information. This structure is defined in the "gis.h" header file. It is discussed in detail under §*12.17 GIS Library Data Structures* [*p. 118*].

12.7.1. The Database Window

Reading and writing the user's database window are done by the following routines:

G_get_window (window) *read the database window*

struct Cell_head *window;

Reads the database window as stored in the WIND file in the user's current mapset into **window.**

An error message is printed and exit( ) is called if there is a problem reading the window.

Note. GRASS applications that read or write cell files should not use this routine, since its use implies that the active program window will not be used. Programs that read or write cell file data (or vector data) can query the active program window using *G_window_rows*(*p.78*) and *G_window_cols*(*p.78*).

G_put_window (window) *write the database window*

struct Cell_head *window;

Writes the database window file (WIND) in the user's current mapset from **window.**

Returns 1 if the window is written ok. Returns -1 if not (no diagnostic message is printed).

Warning. Since this routine actually changes the database window, it should only be called by programs which the user knows will change the window. It is probably fair to say that under GRASS 3.0 only the *window, Gwindow,* and *d.window* programs should call this routine.

There is another database window. This window is the default window for the location. The default window provides the user with a "starting" window, i.e., a window to begin with and return to as a reference point. The GRASS programs *window* and *Gwindow* allow the user to set their database window from the default window. (See §*4.6 Permanent Mapset* [*p.19*] for a discussion of the default window.) The following routine reads this window:

G_get_default_window (window) *read the default window*

    struct Cell_head *window;

Reads the default window for the location into **window.**

An error message is printed and exit( ) is called if there is a problem reading the default window.

12.7.2. The Active Program Window

The active program window is the one that is used when reading and writing cell file data. This window determines the resampling when reading cell data. It also determines the extent and resolution of new cell files.

Initially the active program window and the user's database window are the same, but the programmer can make them different. The following routines manage the active program window.

G_window_rows ( ) *number of rows in active window*

G_window_cols ( ) *number of columns in active window*

These routines return the number of rows and columns (respectively) in the active program window. Before cell files can be read or written, it is necessary to known how many rows and columns are in the active window. For example:

```
int nrows, cols;
int row, col;

nrows = G_window_rows( );
ncols = G_window_cols( );
for (row = 0; row < nrows; row++)
{
    read row ...

    for (col = 0; col < ncols; col++)
    {
        process col ...
    }
}
```

G_set_window (window) *set the active window*

struct Cell_head *window;

This routine sets the active window from **window.** Setting the active window does not change the WIND file in the database. It simply changes the window for the duration of the program.[9]

A warning message is printed and -1 returned if **window** is not valid. Otherwise 1 is returned.

Note. This routine overrides the window as set by the user. Its use should be very limited since it changes what the user normally expects to happen. If this routine is not called, then the active window will be the same as what is in the user's WIND file.

Warning. Calling this routine with already opened cell files has some side effects. If there are cell files which are open for reading, they will be read into the newly set window, not the window that was active when they were opened. However, CELL buffers allocated for reading the cell files are not automatically reallocated. The program must reallocate them explicitly. Also, this routine does not change the window for cell files which are open for writing. The window that was active when the open occurred still applies to these files.

G_get_set_window (window) *get the active window*

struct Cell_head *window;

Gets the values of the currently active window into **window.** If *G_set_window(p. 79)* has been called, then the values set by that call are retrieved. Otherwise the user's database window is retrieved.

Note. For programs that read or write cell data, and really need the full window information, this routine is preferred over *G_get_window(p. 77)*. However, since *G_window_rows(p. 78)* and *G_window_cols(p. 78)* return the number of rows and columns in the active window, the programmer should consider whether or not the full window information is really needed before using this routine.

The following routines return information about the cartographic projection and zone. See *§9.1 Window (p. 47)* for more information about these values.

[9] However, the new window setting is not retained across the UNIX exec() call. This implies that G_set_window() cannot be used to set the window for a program to be executed using the system() or popen() routines.

G_projection ( ) *query cartographic projection*

This routine returns a code indicating the projection for the active window. The current values are:

0	unreferenced x,y (imagery data),
1	UTM,
2	State Plane.[11]

Others may be added in the future.

char *
G_projection_name (proj) *query cartographic projection*

int proj;

Returns a pointer to a string which is a printable name for projection code **proj** (as returned by *G_projection(p.80)*). Returns NULL if **proj** is not a valid projection.

G_zone ( ) *query cartographic zone*

This routine returns the zone for the active window. The meaning for the zone depends on the projection. For example zone 18 for projection type 1 would be UTM zone 18.

12.8. Cell File Processing

Cell files are the heart and soul of GRASS. All analyses are performed with cell file data. Because of this, a suite of routines which process cell file data has been provided.

The processing of cell files consists of determining which cell file or files are to be processed (either by prompting the user or as specified on the program command line), locating the cell file in the database, opening the cell file, dynamically allocating i/o buffers, reading or writing the cell file, closing the cell file, and creating support files for newly created cell files.

All cell file data is of type CELL[12], which is defined in "gis.h".

[11] State Plane is not yet fully supported in GRASS.

[12] See *Appendix B. The CELL Data Type* (p. 237) for a discussion of the CELL type and how to use it (and avoid misusing it).

12.8.1. Prompting for Cell Files

The following routines interactively prompt the user for a cell file name. In each, the **prompt** string will be printed as the first line of the full prompt which asks the user to enter a cell file name. If **prompt** is the empty string "" then an appropriate prompt will be substituted. The name that the user enters is copied into the **name** buffer.[13] These routines have a built-in 'list' capability which allows the user to get a list of existing cell files.

The user is required to enter a valid cell file name, or else hit the RETURN key to cancel the request. If the user enters an invalid response, a message is printed, and the user is prompted again. If the user cancels the request, the NULL pointer is returned. Otherwise the mapset where the cell file lives or is to be created is returned. Both the name and the mapset are used in other routines to refer to the cell file.

char *
G_ask_cell_old (prompt, name) *prompt for existing cell file*

    char *prompt;
    char *name;

Asks the user to enter the name of an existing cell file in any mapset in the database.

char *
G_ask_cell_in_mapset (prompt, name) *prompt for existing cell file*

    char *prompt;
    char *name;

Asks the user to enter the name of an existing cell file in the current mapset.

char *
G_ask_cell_new (prompt, name) *prompt for new cell file*

    char *prompt;
    char *name;

Asks the user to enter a name for a cell file which does not exist in the current mapset.

Here is an example of how to use these routines. Note that the programmer must handle the NULL return properly:

[13] The size of **name** should be large enough to hold any GRASS file name. Most systems allow file names to be quite long. It is recommended that name be declared *char name[50]*.

```
char *mapset;
char name[50];

mapset = G_ask_cell_old("Enter cell file to be processed", name);
if (mapset == NULL)
    exit(0);
```

12.8.2. Finding Cell Files in the Database

Non-interactive programs cannot make use of the interactive prompting routines described above. For example, a command line driven program may require a cell file name as one of the command arguments. GRASS allows the user to specify cell file names (or any other database file) either as a simple unqualified name, such as "soils", or as a fully qualified name, such as "soils in *mapset*", where *mapset* is the mapset where the cell file is to be found. Often only the unqualified cell file name is provided on the command line.

The following routines search the database for cell files:

char *
G_find_cell (name, mapset) *find a cell file*

char *
G_find_cell2 (name, mapset) *find a cell file*

```
char *name;
char *mapset;
```

Look for the cell file **name** in the database. The **mapset** parameter can either be the empty string "", which means search all the mapsets in the user's current mapset search path,[14] or it can be a specific mapset name, which means look for the cell file only in this one mapset (for example, in the current mapset).

If found, the mapset where the cell file lives is returned. If not found, the NULL pointer is returned.

The difference between these two routines is that if the user specifies a fully qualified cell file which exists, then G_find_cell2( ) modifies **name** by removing the "in *mapset*" while G_find_cell( ) does not.[15] Normally, the GRASS programmer need not worry about qualified vs. unqualified names since all library routines handle both forms. However, if the programmer wants the name to be

[14] See §*4.7.1 Mapset Search Path* (*p. 20*) for more details about the search path.

[15] Be warned that G_find_cell2( ) should not be used directly on a command line argument, since modifying argv[ ] may not be valid. The argument should be copied to another character buffer which is then passed to G_find_cell2( ).

returned unqualified (for displaying the name to the user, or storing it in a data file, etc.), then G_find_cell2( ) should be used.

For example, to find a cell file anywhere in the database:

```
char name[50];
char *mapset;


if ((mapset = G_find_cell(name,"")) == NULL)
    /* not found */
```

To check that the cell file exists in the current mapset:

```
char name[50];


if (G_find_cell(name,G_mapset( )) == NULL)
    /* not found */
```

12.8.3. Opening an Existing Cell File

The following routine opens the cell file **name** in **mapset** for reading.

The cell file **name** and **mapset** can be obtained interactively using *G_ask_cell_old(p.81)* or *G_ask_cell_in_mapset(p.81)*, and non-interactively using *G_find_cell(p.82)* or *G_find_cell2(p.82)*.

G_open_cell_old (name, mapset) *open an existing cell file*

```
char *name;
char *mapset;
```

This routine opens the cell file **name** in **mapset** for reading.

A non-negative file descriptor is returned if the open is successful. Otherwise a diagnostic message is printed and a negative value is returned.

This routine does quite a bit of work. Since GRASS users expect that all cell files will be resampled into the current window, the resampling index for the cell file is prepared by this routine after the file is opened. The resampling is based on the active program window.[16] Preparation required for reading the various cell file formats[17] is also done.

[16] See also §*12.7 The Window* (*p. 76*).

[17] See §*5.2 Grid Cell File Format* (*p. 24*) for an explanation of the various cell file formats.

12.8.4. Creating and Opening New Cell Files

The following routines create the new cell file **name** in the current mapset[18] and open it for writing. The cell file **name** should be obtained interactively using *G_ask_cell_new(p.81)*. If obtained non-interactively (e.g., from the command line), *G_legal_filename(p.72)* should be called first to make sure that **name** is a valid GRASS file name.

Note. It is not an error for **name** to already exist. New cell files are actually created as temporary files and moved into the cell directory when closed. This allows an existing cell file to be read at the same time that it is being re-written. The interactive routine *G_ask_cell_new(p.81)* guarantees that **name** will not exist, but if **name** is obtained from the command line, **name** may exist. In this case *G_find_cell(p.82)* could be used to see if **name** exists.

Warning. However, there is a subtle trap. The temporary file, which is created using *G_tempfile(p.108)*, is named using the current process id. If the new cell file is opened by a parent process which exits after creating a child process using fork( ),[19] the cell file may never get created since the temporary file would be associated with the parent process, not the child. GRASS management automatically removes temporary files associated with processes that are no longer running. If fork( ) must be used, the safest course of action is to create the child first, then open the cell file. (See the discussion under *G_tempfile(p.108)* for more details.)

G_open_cell_new (name) *open a new cell file (sequential)*

    char *name;

Creates and opens the cell file **name** for writing by *G_put_map_row(p.88)* which writes the file row by row in sequential order. The cell file data will be compressed as it is written.

A non-negative file descriptor is returned if the open is successful. Otherwise a diagnostic message is printed and a negative value is returned.

[18] GRASS doesn't allow files to be created outside the current mapset. See §4.7 *Database Access Rules* (p.20).

[19] See also *G_fork(p.116)*.

G_open_cell_new_random (name) *open a new cell file (random)*

char *name;

Creates and opens the cell file **name** for writing by *G_put_map_row_random(p.88)* which allows writing the cell file in a random fashion. The file will be created uncompressed.[20]

A non-negative file descriptor is returned if the open is successful. Otherwise a diagnostic message is printed and a negative value is returned.

G_open_cell_new_uncompressed (name) *open a new cell file (uncompressed)*

char *name;

Creates and opens the cell file **name** for writing by *G_put_map_row(p.88)* which writes the file row by row in sequential order. The cell file will be in uncompressed format when closed.

A non-negative file descriptor is returned if the open is successful. Otherwise a warning message is printed on stderr and a negative value is returned.

General use of this routine is not recommended.[21] This routine is provided so the *uncompress* program can create uncompressed cell files.

12.8.5. Allocating Cell I/O Buffers

Since there is no pre-defined limit for the number of columns in the window,[22] buffers which are used for reading and writing cell data must be dynamically allocated.

[20] Nor will the file get automatically compressed when it is closed. If a compressed file is desired, it can be compressed explicitly after closing by a system call: system("compress *name*").

[21] At present, automatic cell file compression will create files which, in most cases, are smaller than if they were uncompressed. In certain cases, the compressed cell file may be larger. This can happen with imagery data, which don't compress well at all. However, the size difference is usually small. Since future enhancements to the compression method may improve compression for imagery data as well, it is best to create compressed cell files in all cases.

[22] See *G_window_cols(p. 78)* to find the number of columns in the window.

CELL *
G_allocate_cell_buf ( ) *allocate a cell buffer*

This routine allocates a buffer of type CELL just large enough to hold one row of cell data (based on the number of columns in the active window).

```
CELL *cell;
cell = G_allocate_cell_buf( );
```

If larger buffers are required, the routine *G_malloc(p. 76)* can be used.

If sufficient memory is not available, an error message is printed and exit( ) is called.

G_zero_cell_buf (buf) *zero a cell buffer*

CELL *buf;

This routines assigns each member of the cell buffer array **buf** to zero. It assumes that **buf** has been allocated using *G_allocate_cell_buf(p. 86)*.

12.8.6. Reading Cell Files

Cell file data can be thought of as a two-dimensional matrix. The routines described below read *one* full row of the matrix. It should be understood, however, that the number of rows and columns in the matrix is determined by the window, not the cell file itself. Cell file data is always read resampled into the window.[23] This allows the user to specify the coverage of the database during analyses. It also allows databases to consist of cell files which do not cover exactly the same area, or do not have the same grid cell resolution. When cell files are resampled into the window, they all "look" the same.

Note. The rows and columns are specified "C style", i.e., starting with 0.

[23] The GRASS window is discussed from a user perspective in §*9.1 Window* [p. 47] and from a programmer perspective in §*12.7 The Window* [p. 76]. The routines which are commonly used to determine the number of rows and columns in the window are *G_window_rows(p. 78)* and *G_window_cols(p. 78)*.

G_get_map_row (fd, cell, row) *read a cell file*

```
int fd;
CELL *cell;
int row;
```

This routine reads the specified **row** from the cell file open on file descriptor **fd** (as returned by *G_open_cell_old*(*p.83*)) into the **cell** buffer. The **cell** buffer must be dynamically allocated large enough to hold one full row of cell data. It can be allocated using *G_allocate_cell_buf*(*p.86*).

This routine prints a diagnostic message and returns -1 if there is an error reading the cell file. Otherwise a non-negative value is returned.

G_get_map_row_nomask (fd, cell, row) *read a cell file (without masking)*

```
int fd;
CELL *cell;
int row;
```

This routine reads the specified **row** from the cell file open on file descriptor **fd** into the **cell** buffer like G_get_map_row( ) does. The difference is that masking is suppressed. If the user has a mask set, G_get_map_row( ) will apply the mask but G_get_map_row_nomask( ) will ignore it.

This routine prints a diagnostic message and returns -1 if there is an error reading the cell file. Otherwise a non-negative value is returned.

Note. Ignoring the mask is not generally acceptable. Users expect the mask to be applied. However, is some cases ignoring the mask is justified. For example, the GRASS programs *Gdescribe,* which reads the cell file directly to report all data values in a cell file, or *Gslope.aspect,* which produces slope and aspect from elevation, ignore both the mask and the window. However, the number of GRASS programs which do this should be minimal. See §*9.2 Mask* [*p.48*] for more information about the mask.

12.8.7. Writing Cell Files

The routines described here write cell file data.

G_put_map_row (fd, buf) *write a cell file (sequential)*

```
int fd;
CELL *buf;
```

This routine writes one row of cell data from **buf** to the cell file open on file descriptor **fd.** The cell file must have been opened with *G_open_cell_new(p. 84)*. The cell **buf** must have been allocated large enough for the window, perhaps using *G_allocate_cell_buf(p. 86)*.

If there is an error writing the cell file, a warning message is printed and -1 is returned. Otherwise 1 is returned.

Note. The rows are written in sequential order. The first call writes row 0, the second writes row 1, etc. The following example assumes that the cell file **name** is to be created:

```
int fd, row; nrows;
CELL *buf;

fd = G_open_cell_new (name);
if (fd < 0)
    /* oops - can't open cell file */

buf = G_allocate_cell_buf( );
nrows = G_window_rows( );
for (row = 0; row < nrows; row++)
{
    /* prepare data for this row into buf */

    /* write the data for the row */
    G_put_map_row (fd, buf);
}
```

G_put_map_row_random (fd, buf, row, col, ncells) *write a cell file (random)*

```
int fd;
CELL *buf;
int row, col, ncells;
```

This routine allows random writes to the cell file open on file descriptor **fd.** The cell file must have been opened using *G_open_cell_new_random(p. 85)*. The cell buffer **buf** contains **ncells** columns of data and is to be written into the cell file at the specified **row,** starting at column **col.**

12.8.8. Closing Cell Files

All cell files are closed by one of the following routines, whether opened for reading or for writing.

G_close_cell (fd) *close a cell file*

    int fd;

The cell file opened on file descriptor **fd** is closed. Memory allocated for cell processing is freed. If open for writing, skeletal support files for the new cell file are created as well.

Note. If a program wants to explicitly write support files (e.g., a specific color table) for a cell file it creates, it must do so after the cell file is closed. Otherwise the close will overwrite the support files. See §*12.9 Map Layer Support Routines* [*p. 89*] for routines which write cell support files.

G_unopen_cell (fd) *unopen a cell file*

    int fd;

The cell file opened on file descriptor **fd** is closed. Memory allocated for cell processing is freed. If open for writing, the cell file is not created and the temporary file created when the cell file was opened is removed (see §*12.8.4 Creating and Opening New Cell Files* [*p. 84*]).

This routine is useful when errors are detected and it is desired to not create the new cell file. While it is true that the cell file will not be created if the program exits without closing the file, the temporary file will not be removed at program exit. GRASS database management will eventually remove the temporary file, but the file can be quite large and will take up disk space until GRASS does remove it. Use this routine as a courtesy to the user.

12.9. Map Layer Support Routines

GRASS map layers have a number of support files associated with them. These files are discussed in detail in §*5 Grid Cell Maps* [*p. 23*]. The support files are the *cell header*, the *category* file, the *color* table, the *history* file, and the *range* file. Each support file has its own data structure and associated routines.

12.9.1. Cell Header File

The cell header file contains information describing the geographic extent of the map layer, the grid cell resolution, and the format used to store the data in the cell file. The format of this file is described in §*5.3 Cell Header Format* [*p. 26*]. The routines described below use the *Cell_head* structure which is shown in detail in §*12.17 GIS Library Data Structures* [p. 118].

G_get_cellhd (name, mapset, cellhd) *read the cell header*

```
char *name;
char *mapset;
struct Cell_Head *cellhd;
```

The cell header for the cell file **name** in the specified **mapset** is read into the **cellhd** structure.

If there is an error reading the cell header file, a diagnostic message is printed and -1 is returned. Otherwise, 0 is returned.

Note. If the cell file is a reclass file, the cell header for the referenced cell file is read instead. See §*5.3.2 Reclass Format* [p. 27] for information about reclass files, and *G_is_reclass*(*p. 91*) for distinguishing reclass files from regular cell files.

Note. It is not necessary to get the cell header for a map layer in order to read the cell file data. The routines which read cell file data automatically retrieve the cell header information and use it for resampling the cell file data into the active window.[24] If it is necessary to read the cell file directly without resampling into the active window,[25] then the cell header can be used to set the active window using *G_set_window*(*p. 79*).

G_put_cellhd (name, cellhd) *write the cell header*

```
char *name;
struct Cell_head *cellhd;
```

This routine writes the information from the **cellhd** structure to the cell header file for the map layer **name** in the current mapset.

If there was an error creating the cell header, -1 is returned. No diagnostic is printed. Otherwise, 1 is returned to indicate success.

Note. Programmers should have no reason to use this routine. It is used by *G_close_cell*(*p. 89*) to give new cell files correct cell header files, and by the *support* program to give users a means of creating or modifying cell headers.

---

[24] See §*12.7 The Window* [p. 76].

[25] but see §*9 Window and Mask* [p. 47] for a discussion of when this should and should not be done.

G_is_reclass (name, mapset, r_name, r_mapset) *reclass file?*

```
    char *name;
    char *mapset;
    char *r_name;
    char *r_mapset;
```

This function determines if the cell file **name** in **mapset** is a reclass file. If it is, then the name and mapset of the referenced cell file are copied into the **r_name** and **r_mapset** buffers.

Returns 1 if **name** is a reclass file, 0 if it isn't, and -1 if there was a problem reading the cell header for **name**.

12.9.2. Cell Category File

GRASS map layers have category labels associated with them. The category file is structured so that each category in the cell file can have a one-line description. The format of this file is described in §*5.4 Cell Category File Format* [*p.28*].

The routines described below manage the category file. Some of them use the *Categories* structure which is described in §*12.17 GIS Library Data Structures* [*p.118*].

12.9.2.1. Reading and Writing the Cell Category File

The following routines read or write the category file itself:

G_read_cats (name, mapset, cats) *read cell category file*

```
    char *name;
    char *mapset;
    struct Categories *cats;
```

The category file for cell file **name** in **mapset** is read into the **cats** structure.

If there is an error reading the category file, a diagnostic message is printed and -1 is returned. Otherwise, 0 is returned.

G_write_cats (name, cats) *write cell category file*

```
char *name;
struct Categories *cats;
```

Writes the category file for the cell file **name** in the current mapset from the **cats** structure.

Returns 0 if successful. Otherwise, -1 is returned (no diagnostic is printed).

char *
G_get_cell_title (name, mapset) *get cell title*

```
char *name;
char *mapset;
```

If only the map layer title is needed, it isn't necessary to read the entire category file into memory. This routine gets the title for cell file **name** in **mapset** directly from the category file, and returns a pointer to the title. A legal pointer is always returned. If the map layer doesn't have a title, then a pointer to the empty string "" is returned.

char *
G_put_cell_title (name, title) *change cell title*

```
char *name;
char *title;
```

If it is only desired to change the title for a map layer, it isn't necessary to read the entire category file into memory, change the title, and rewrite the category file. This routine changes the **title** for the cell file **name** in the current mapset directly in the category file. It returns a pointer to the title.

12.9.2.2. Querying and Changing the Categories Structure

The following routines query or modify the information contained in the category structure:

char *
G_get_cat (n, cats) *get a category label*

CELL n;
struct Categories *cats;

This routine looks up category **n** in the **cats** structure and returns a pointer to a string which is the label for the category. A legal pointer is always returned. If the category doesn't exist in **cats**, then a pointer to the empty string "" is returned.

Warning. The pointer that is returned points to a hidden static buffer. Successive calls to G_get_cat( ) overwrite this buffer.

char *
G_get_cats_title (cats) *get title from category structure*

struct Categories *cats;

Map layers store a one-line title in the category structure as well. This routine returns a pointer to the title contained in the **cats** structure. A legal pointer is always returned. If the map layer doesn't have a title, then a pointer to the empty string "" is returned.

G_init_cats (n, title, cats) *initialize category structure*

CELL n;
char *title;
struct Categories *cats;

To construct a new category file, the structure must first be initialized. This routine initializes the **cats** structure, and copies the **title** into the structure. The number of categories is set initially to **n**.

For example:

```
struct Categories cats;

G_init_cats ( (CELL)0, "", &cats);
```

G_set_cat (n, label, cats) *set a category label*

```
CELL n;
char *label;
struct Categories *cats;
```

The **label** is copied into the **cats** structure for category **n**.

G_set_cats_title (title, cats) *set title in category structure*

```
char *title;
struct Categories *cats;
```

The **title** is copied into the **cats** structure.

G_free_cats (cats) *free category structure memory*

```
struct Categories *cats;
```

Frees memory allocated by *G_read_cats*(*p. 91*), *G_init_cats*(*p. 93*) and *G_set_cat*(*p. 94*).

12.9.3. Cell Color Table

GRASS map layers have colors associated with them. The color tables are structured so that each category in the cell file has its own color. The format of this file is described in §*5.5 Cell Color Table Format* [*p. 28*].

The following routines read, create, modify, and write color tables. They use the *Colors* structure which is described in detail in §*12.17 GIS Library Data Structures* [*p. 118*].

G_read_colors (name, mapset, colors) *read map layer color table*

```
char *name;
char *mapset;
struct Colors *colors;
```

The color table for the cell file **name** in the specified **mapset** is read into the **colors** structure.

If the data layer has no color table, a default color table is generated and 0 is returned. If there is an error reading the color table, a diagnostic message is printed and -1 is returned. If the color table is read ok, 1 is returned.

G_write_colors (name, mapset, colors) *write map layer color table*

```
char *name;
char *mapset;
struct Colors *colors;
```

The color table is written for the cell file **name** in the specified **mapset** from the **colors** structure.

If there is an error, -1 is returned. No diagnostic is printed. Otherwise, 1 is returned.

The **colors** structure must be created properly, i.e., *G_init_colors*(*p. 96*) to initialize the structure and *G_set_color*(*p. 96*) to set the category colors.[26]

Note. The calling sequence for this function deserves special attention. The **mapset** parameter seems to imply that it is possible to overwrite the color table for a cell file which is in another mapset. However, this isn't what actually happens. It is very useful for users to create their own color tables for cell files in other mapsets, but without overwriting other users' color tables for the same cell file. If **mapset** is the current mapset, then the color file for **name** will be overwritten by the new color table. But if **mapset** is not the current mapset, then the color table is actually written in the current mapset under the **colr2** element as: colr2/*mapset*/*name*.

G_get_color (cat, red, green, blue, colors) *get a category color*

```
CELL cat;
int *red;
int *green;
int *blue;
struct Colors *colors;
```

The **red, green,** and **blue** intensities for the color associated with category **cat** are extracted from the **colors** structure. The intensities will be in the range 0–255.

[26] These routines are called by higher level routines which read or create entire color tables, such as *G_read_colors*(*p. 94*) or *G_make_color_ramp*(*p. 97*).

G_init_colors (colors) *initialize color structure*

```
struct Colors *colors;
```

The **colors** structure is initialized for subsequent calls to *G_set_color(p.96)*.

G_set_color (cat, red, green, blue, colors) *set a category color*

```
CELL cat;
int red;
int green;
int blue;
struct Colors *colors;
```

The **red, green,** and **blue** intensities for the color associated with category **cat** are set in the **colors** structure. The intensities must be in the range 0–255. Values below zero are set as zero, values above 255 are set as 255.

Note. The **colors** structure must have been initialized by *G_init_colors(p.96)*.

G_free_colors (colors) *free color structure memory*

```
struct Colors *colors;
```

The dynamically allocated memory associated with the **colors** structure is freed.

Note. This routine may be used after *G_read_colors(p.94)* as well as after *G_init_colors(p.96)*.

The following routines generate entire color tables. The tables are loaded into a **colors** structure based on a range of category values from **min** to **max.** The range of values can be obtained, for example, using *G_read_range(p.99)*.

Note. The color tables are generated without information about any particular cell file. These color tables may be created for a cell file, but they may also be generated for loading graphics colors.

These routines return -1 if **min** is greater than **max,** 1 otherwise.

G_make_aspect_colors (colors, min, max) *make aspect colors*

```
struct Colors *colors;
CELL min, max;
```

Generates a color table for aspect data.

G_make_color_ramp (colors, min, max) *make color ramp*

```
struct Colors *colors;
CELL min, max;
```

Generates a color table with 3 sections: red only, green only, and blue only, each increasing from none to full intensity. This table is good for continuous data like elevation.

G_make_color_wave (colors, min, max) *make color wave*

```
struct Colors *colors;
CELL min, max;
```

Generates a color table with 3 sections: red only, green only, and blue only, each increasing from none to full intensity and back down to none. This table is good for continuous data like elevation.

Note. This routine requires that the $(MATHLIB) be loaded as well.

G_make_grey_scale (colors, min, max) *make linear grey scale*

```
struct Colors *colors;
CELL min, max;
```

Generates a grey scale color table. Each color is a level of grey, increasing from black to white.

G_make_rainbow_colors (colors, min, max) *make rainbow colors*

```
struct Colors *colors;
CELL min, max;
```

Generates a color table based on rainbow colors. The table generated here uses yellow, green, blue, indigo, violet, red. (Normal rainbow colors are red, orange, yellow, green, blue, indigo, and violet.) This table is good for continuous data like elevation.

G_make_random_colors (colors, min, max) *make random colors*

```
struct Colors *colors;
CELL min, max;
```

Generates random colors. Good as a first pass at a color table for nominal data.

G_make_red_yel_grn (colors, min, max) *make red,yellow,green colors*

```
struct Colors *colors;
CELL min, max;
```

Generates a color table simliar to what *G_make_rainbow_colors(p.97)* creates, except that the table starts at red, passes through yellow, and ends with green.

12.9.4. Cell History File

The history file contains documentary information about the cell file: who created it, when it was created, what was the original data source, what information is contained in the cell file, etc. This file is discussed in *§5.6 Cell History File* [p.29].

The following routines manage this file. They use the *History* structure which is described in *§12.17 GIS Library Data Structures* [p.118].

Note. This structure has existed relatively unmodified since the inception of GRASS. It is in need of overhaul. Programmers should be aware that future versions of GRASS may no longer support either the routines or the data structure which support the history file.

G_read_history (name, mapset, history) *read cell history file*

```
char *name;
char *mapset;
struct History *history;
```

This routine reads the history file for the cell file **name** in **mapset** into the **history** structure.

A diagnostic message is printed and -1 is returned if there is an error reading the history file. Otherwise, 0 is returned.

G_write_history (name, history) *write cell history file*

```
char *name;
struct History *history;
```

This routine writes the history file for the cell file **name** in the current mapset from the **history** structure.

A diagnostic message is printed and -1 is returned if there is an error writing the history file. Otherwise, 0 is reurned.

Note. The **history** structure should first be initialized using *G_short_history(p. 99)*.

G_short_history (name, type, history) *initialize history structure*

```
char *name;
char *type;
struct History *history;
```

This routine initializes the **history** structure, recording the date, user, program name and the cell file **name** structure. The **type** is an anachronism from earlier versions of GRASS and should be specified as "cell".

Note. This routine only initializes the data structure. It does not write the history file.

12.9.5. Cell Range File

The following routines manage the cell range file. This file contains the minimum and maximum values found in the cell file. The format of this file is described in §*5.7 Cell Range File* [p. 29].

The routines below use the *Range* data structure which is described in §*12.17 GIS Library Data Structures* [p. 118].

G_read_range (name, mapset, range) *read cell range*

```
char *name;
char *mapset;
struct Range *range;
```

This routine reads the range information for the cell file **name** in **mapset** into the **range** structure.

A diagnostic message is printed and -1 is returned if there is an error reading the range file. Otherwise, 0 is returned.

G_write_range (name, range) *write cell range*

```
char *name;
struct Range *range;
```

This routine writes the range information for the cell file **name** in the current mapset from the **range** structure.

A diagnostic message is printed and -1 is returned if there is an error writing the range file. Otherwise, 0 is returned.

The range structure must be initialized and updated using the following routines:

G_init_range (range) *initialize range structure*

```
struct Range *range;
```

Initializes the **range** structure for updates by *G_update_range(p. 100)* and *G_row_update_range(p. 100)*.

G_update_range (cat, range) *update range structure*

```
CELL cat;
struct Range *range;
```

Compares the **cat** value with the minimum and maximum values in the **range** structure, modifying the range if **cat** extends the range.

G_row_update_range (cell, n, range) *update range structure*

```
CELL *cell;
int n;
struct Range *range;
```

This routine updates the **range** data just like *G_update_range(p. 100)*, but for **n** values from the **cell** array.

12.10. Vector File Processing

The *GIS Library* contains some functions related to vector file processing. These include prompting the user for vector files, locating vector files in the database, opening vector files, and a few others.

Note. Most vector file processing, however, is handled by routines in the *Dig Library,* which is described in §*13 Dig Library* (*p. 123*).

12.10.1. Prompting for Vector Files

The following routines interactively prompt the user for a vector file name. In each, the **prompt** string will be printed as the first line of the full prompt which asks the user to enter a vector file name. If **prompt** is the empty string "" then an appropriate prompt will be substituted. The name that the user enters is copied into the **name** buffer.[27] These routines have a built-in 'list' capability which allows the user to get a list of existing vector files.

The user is required to enter a valid vector file name, or else hit the RETURN key to cancel the request. If the user enters an invalid response, a message is printed, and the user is prompted again. If the user cancels the request, the NULL pointer is returned. Otherwise the mapset where the vector file lives or is to be created is returned. Both the name and the mapset are used in other routines to refer to the vector file.

char *
G_ask_vector_old (prompt, name) *prompt for an existing vector file*

    char *name;
    char *mapset;

Asks the user to enter the name of an existing vector file in any mapset in the database.

char *
G_ask_vector_in_mapset (prompt, name) *prompt for an existing vector file*

    char *name;
    char *mapset;

Asks the user to enter the name of an existing vector file in the current mapset.

char *
G_ask_vector_new (prompt, name) *prompt for a new vector file*

    char *name;
    char *mapset;

Asks the user to enter a name for a vector file which does not exist in the current mapset.

Here is an example of how to use these routines. Note that the programmer must handle the NULL return properly:

[27] The size of **name** should be large enough to hold any GRASS file name. Most systems allow file names to be quite long. It is recommended that name be declared *char name[50]*.

```
char *mapset;
char name[50];

mapset = G_ask_vector_old("Enter vector file to be processed", name);
if (mapset == NULL)
    exit(0);
```

12.10.2. Finding Vector Files in the Database

Non-interactive programs cannot make use of the interactive prompting routines described above. For example, a command line driven program may require a vector file name as one of the command arguments. GRASS allows the user to specify vector file names (or any other database file) either as a simple unqualified name, such as "roads", or as a fully qualified name, such as "roads in *mapset*", where *mapset* is the mapset where the vector file is to be found. Often only the unqualified vector file name is provided on the command line.

The following routines search the database for vector files:

G_find_vector (name, mapset) *find a vector file*

G_find_vector2 (name, mapset) *find a vector file*

```
char *name;
char *mapset;
```

Look for the vector file **name** in the database. The **mapset** parameter can either be the empty string "", which means search all the mapsets in the user's current mapset search path,[28] or it can be a specific mapset name, which means look for the vector file only in this one mapset (for example, in the current mapset).

If found, the mapset where the vector file lives is returned. If not found, the NULL pointer is returned.

The difference between these two routines is that if the user specifies a fully qualified vector file which exists, then G_find_vector2( ) modifies **name** by removing the "in *mapset*" while G_find_vector( ) does not.[29] Normally, the GRASS programmer need not worry about qualified vs. unqualified names since all library routines handle both forms. However, if the programmer wants the name to be returned unqualified (for displaying the name to the user, or storing it in a data file, etc.), then G_find_vector2( ) should be used.

[28] See §4.7.1 *Mapset Search Path* [p. 20] for more details about the search path.

[29] Be warned that G_find_vector2( ) should not be used directly on a command line argument, since modifying argv[ ] may not be valid. The argument should be copied to another character buffer which is then passed to G_find_vector2( ).

For example, to find a vector file anywhere in the database:

```
char name[50];
char *mapset;


if ((mapset = G_find_vector(name,"")) == NULL)
    /* not found */
```

To check that the vector file exists in the current mapset:

```
char name[50];


if (G_find_vector(name,G_mapset()) == NULL)
    /* not found */
```

12.10.3. Opening an Existing Vector File

The following routine opens the vector file **name** in **mapset** for reading.

The vector file **name** and **mapset** can be obtained interactively using *G_ask_vector_old*(p. 101) or *G_ask_vector_in_mapset*(p. 101), and non-interactively using *G_find_vector*(p. 102) or *G_find_vector2*(p. 102).

FILE *
G_fopen_vector_old (name, mapset) *open an existing vector file*

```
char *name;
char *mapset;
```

This routine opens the vector file **name** in **mapset** for reading.

A file descriptor is returned if the open is successful. Otherwise the NULL pointer is returned (no diagnostic message is printed).

The file descriptor can then be used with routines in the *Dig Library* to read the vector file. (See §*13 Dig Library* [p. 123].)

Note. This routine does not call any routines in the *Dig Library*; No initialization of the vector file is done by this routine, directly or indirectly.

12.10.4. Creating and Opening New Vector Files

The following routine creates the new vector file **name** in the current mapset[30] and opens it for writing. The vector file **name** should be obtained interactively using *G_ask_vector_new*(*p. 101*). If obtained non-interactively (e.g., from the command line), *G_legal_filename*(*p. 72*) should be called first to make sure that **name** is a valid GRASS file name.

Warning. If **name** already exists, it will be erased and re-created empty. The interactive routine *G_ask_vector_new*(*p. 101*) guarantees that **name** will not exist, but if **name** is obtained from the command line, **name** may exist. In this case *G_find_vector*(*p. 102*) could be used to see if **name** exists.

FILE *
G_fopen_vector_new (name) *open a new vector file*

    char *name;

Creates and opens the vector file **name** for writing.

A file descriptor is returned if the open is successful. Otherwise the NULL pointer is returned (no diagnostic message is printed).

The file descriptor can then be used with routines in the *Dig Library* to write the vector file. (See §*13 Dig Library* [*p. 123*].)

Note. This routine does not call any routines in the *Dig Library*; No initialization of the vector file is done by this routine, directly or indirectly. Also, only the vector file itself (i.e., the *dig* file), is created. None of the other vector support files are created, removed, or modified in any way.

12.10.5. Reading and Writing Vector Files

Reading and writing vector files is handled by routines in the *Dig Library*. See §*13 Dig Library* [*p. 123*] for details.

12.10.6. Vector Category File

GRASS vector files have category labels associated with them. The category file is structured so that each category in the vector file can have a one-line description.

[30] GRASS doesn't allow files to be created outside the current mapset. See §*4.7 Database Access Rules* [*p. 20*].

The routines described below read and write the vector category file. They use the *Categories* structure which is described in §*12.17 GIS Library Data Structures* [*p. 118*].

Note. The vector category file has exactly the same structure as the cell category file. In fact, it exists so that the program *vect.to.cell* can convert a vector file to a cell file that has an up-to-date category file.

The routines described in §*12.9.2.2 Querying and Changing the Categories Structure* [*p. 92*] which modify the *Categories* structure can therefore be used to set and change vector categories as well.

G_read_vector_cats (name, mapset, cats) *read vector category file*

```
char *name;
char *mapset;
struct Categories *cats;
```

The category file for vector file **name** in **mapset** is read into the **cats** structure.

If there is an error reading the category file, a diagnostic message is printed and -1 is returned. Otherwise, 0 is returned.

G_write_vector_cats (name, cats) *write vector category file*

```
char *name;
struct Categories *cats;
```

Writes the category file for the vector file **name** in the current mapset from the **cats** structure.

Returns 0 if successful. Otherwise, -1 is returned (no diagnostic is printed).

12.11. Site List Processing

GRASS has a point database capabilitity called *sites,* which manages a database of point or site information. The *sites* program provides the majority of the analytical capabilities within GRASS for site data. The routines described here provide programmers with mechanisms for reading existing site list files and for creating new ones. The reader should also see §7 *Point Data: Site List Files* [*p. 39*] for more details about the site list files.

12.11.1. Prompting for Site List Files

The following routines interactively prompt the user for a site list file name. In each, the **prompt** string will be printed as the first line of the full prompt which asks the user to enter a site list file name. If **prompt** is the empty string "" then an appropriate prompt will be substituted. The name that the user enters is copied into the **name** buffer.[31] These routines have a built-in 'list' capability which allows the user to get a list of existing site list files.

The user is required to enter a valid site list file name, or else hit the RETURN key to cancel the request. If the user enters an invalid response, a message is printed, and the user is prompted again. If the user cancels the request, the NULL pointer is returned. Otherwise the mapset where the site list file lives or is to be created is returned. Both the name and the mapset are used in other routines to refer to the site list file.

char *
G_ask_sites_old (prompt, name) *prompt for existing site list file*

    char *prompt;
    char *name;

Asks the user to enter the name of an existing site list file in any mapset in the database.

char *
G_ask_sites_in_mapset (prompt, name) *prompt for existing site list file*

    char *prompt;
    char *name;

Asks the user to enter the name of an existing site list file in the current mapset.

char *
G_ask_sites_new (prompt, name) *prompt for new site list file*

    char *prompt;
    char *name;

Asks the user to enter a name for a site list file which does not exist in the current mapset.

Here is an example of how to use these routines. Note that the programmer must handle the NULL return properly:

[31] The size of **name** should be large enough to hold any GRASS file name. Most systems allow file names to be quite long. It is recommended that name be declared *char name[50]*.

```
char *mapset;
char name[50];

mapset = G_ask_sites_old("Enter site list file to be processed", name);
if (mapset == NULL)
    exit(0);
```

12.11.2. Opening Site List Files

The following routines open site list files:

FILE *
G_fopen_sites_new (name) *open a new site list file*

    char *name;

Creates an empty site list file **name** in the current mapset and opens it for writing.

Returns an open file descriptor if successful. Otherwise, returns NULL.

FILE *
G_fopen_sites_old (name, mapset) *open an existing site list file*

    char *name;
    char *mapset;

Opens the site list file **name** in **mapset** for reading.

Returns an open file descriptor if successful. Otherwise, returns NULL.

12.11.3. Reading and Writing Site List Files

G_get_site (fd, east, north, desc) *read site list file*

    FILE *fd;
    double *east, *north;
    char **desc;

This routine sets **east** and **north** for the next "point" from the site list file open on file descriptor **fd** (as returned by *G_fopen_sites_old(p. 107)*), and **desc** is set to point to the description of the site.

Returns: 1 got a site; -1 no more sites.

For example:

```
double east, north;
char *desc;
FILE *fd;

fd = G_fopen_site_old (name, mapset);
while (G_get_site (fd, &east, &north, &desc) > 0)
        printf ("%lf %lf %s\n", east, north, desc);
```

Note: desc points to static memory, so each call overrides the description from the previous call.

G_put_site (fd, east, north, desc) *write site list file*

```
FILE *fd;
double east, north;
char *desc;
```

Writes the **east** and **north** coordinates and site description **desc** to the site file opened on file descriptor **fd** (as returned by *G_fopen_sites_new*(*p. 107*)).

12.12. Temporary Files

Often it is necessary for programs to use temporary files to store information that is only useful during the program run. After the program finishes, the information in the temporary file is no longer needed and the file is removed. Commonly it is required that temporary file names be unique from invocation to invocation of the program. It would not be good for a fixed name like "/tmp/mytempfile" to be used. If the program were run by two users at the same time, they would use the same temporary file.

The following routine generates temporary file names which are unique within the program and across all GRASS programs.

char *
G_tempfile ( ) *returns a temporary file name*

This routine returns a pointer to a string containing a unique file name that can be used as a temporary file within the program. Successive calls to G_tempfile( ) will generate new names.

Only the file name is generated. The file itself is not created. To create the file, the program must use standard UNIX functions which create and open files, e.g., creat( ) or fopen( ).

The programmer should take reasonable care to remove (unlink) the file before the program exits. However, GRASS database management will eventually remove all temporary files created by G_tempfile( ) that have been left behind by the programs which created them.

Note. The temporary files are created in the GRASS database rather than under /tmp. This is done for two reasons. The first is to increase the likelihood that enough disk is available for large temporary files since /tmp may be a very small file system. The second is so that abandoned temporary files can be automatically removed (but see the warning below).

Warning. The temporary files are named, in part, using the process id of the program. GRASS database management will remove these files only if the program which created them is no longer running. However, this feature has a subtle trap. Programs which create child processes (using the UNIX fork( )[32] routine) should let the child call G_tempfile( ). If the parent does it and then exits, the child may find that GRASS has removed the temporary file since the process which created it is no longer running.

12.13. Command Line Parsing

The following two routines provide a mechanism for command line parsing. Use of these routines will standardize GRASS commands that expect command line arguments.

The routines are described first, followed by a short example (on page 112) of their usage.

G_parse_command (argc, argv, keys, stash) *parse command line*

```
int argc;
char *argv[ ];
struct Command_keys *keys;
int (*stash)( );
```

This routine parses command lines in any of the following formats:

command value1 value2 value3 value4
the options are in the correct positions

command value1 - - value4
the options are in the correct positions, where minuses (-) are interpreted as "accept the default for this position"

command opt2=value2 opt4=value4 opt3=value3 opt1=value1
the options are in mixed order, but the correct position is ascertained by looking for the "opt" string in the **keys** structure, which contains the "correct" position for the option.

command value1 - opt4=value4
a mixed form of the above formats

[32] See also *G_fork(p. 116)*.

The command line parameters **argv** and the number of parameters **argc** from the main( ) routine are passed directly to *G_parse_command*( ).

The option names and positions are specified in **keys**, which is an array of *Command_keys* structures, defined as:

```
struct Command_keys
{
        char *alias;
        int position;
};
```

The **keys** array is terminated by a NULL *alias*. For example:

```
struct Command_keys keys[ ] =
{
        {"name", 1},
        {"color", 2},
        {NULL, 0}
};
```

Once a position is determined, either by actual position or by deduction, the position number and option value are sent to the specified routine **stash**( ), which should "stash" the information somewhere for later use by the program. This routine must be defined as:

```
stash (position, value)
        int position;
        char *value;
```

and return 0 if the **value** is valid, 1 otherwise.

G_parse_command( ) returns the following codes:

1	There are no arguments on the command line, or the first argument is the word "help" (a usage message is printed for the user),
0	There were no errors on the command line. (This doesn't imply that all parameters were specified, just that those specified were valid).
< 0	There are errors on the command line (nothing is printed for the user).

G_parse_command_usage (program, keys, format) *command line usage message*

```
char *program;
struct Command_keys *keys;
int format;
```

This routine prints a standard usage message for the **program** (usually argv[0]) based on the options described in the **keys** parameter (which is the same as that passed to *G_parse_command*(*p. 109*)). The **format** of the message may either be USAGE_SHORT for a terse format, or USAGE_LONG for a longer format.

Example. The following example parses a command which expects two arguments: a *name*, and a *color*:

```
#include "gis.h"

struct Command_keys keys[ ] =
{
    {"name", 1},
    {"color", 2},
    {NULL, 0}
};

static char name[50];
static char color[50];
static int have_name = 0;
static int have_color = 0;

static
stash(position, value)
    int position;
    char *value;
{
    switch (position)
    {
    case 1:
        strcpy (name, value);
        have_name = 1;
        return 0;
    case 2:
        strcpy (color, value);
        have_color = 1;
        return 0;
    }
    return 1;
}

main (argc, argv) char *argv[ ];
{
    int stat;

    G_gisinit (argv[0]);

    stat = G_parse_command (argc, argv, keys, stash);
    if (stat != 0 || !have_name || !have_color)
    {
        if (stat <= 0)
            G_parse_command_usage (argv[0], keys, USAGE_LONG);
        exit(1);
    }

    /* parsing complete. proceed to function implementation */

    exit(0);
}
```

12.14. String Manipulation Functions

This section describes some routines which perform string manipulation. Strings have the usual C meaning: a NULL terminated array of characters.

These next 3 routines copy characters from one string to another.

char *
G_strcpy (dst, src) *copy strings*

  char *dst, *src;

Copies the **src** string to **dst** up to and including the NULL which terminates the **src** string. Returns **dst.**

char *
G_strncpy (dst, src, n) *copy strings*

  char *dst, *src;
  int n;

Copies at most **n** characters from the **src** string to **dst.** If **src** contains less than **n** characters, then only those characters are copied. A NULL byte is added at the end of **dst.** This implies that **dst** should be at least **n**+1 bytes long. Returns **dst.**

Note. This routine varies from the UNIX strncpy( ) in that G_strncpy( ) ensures that **dst** is NULL terminated, while strncpy( ) does not.

char *
G_strcat (dst, src) *concatentate strings*

  char *dst, *src;

Appends the **src** string to the end of the **dst** string, which is then NULL terminated. Returns **dst.**

These next 2 routines remove unwanted white space from a single string.

char *
G_squeeze (s) *remove unnecessary white space*

  char *s;

Leading and trailing white space is removed from the string **s** and internal white space which is more than one character is reduced to a single space character. White space here means spaces, tabs, linefeeds, newlines, and formfeeds. Returns **s.**

G_strip (s) *remove leading/training white space*

char *s;

Leading and trailing white space is removed from the string **s**. White space here means only spaces and tabs. There is no return value.

This next routine copies a string to allocated memory.

char *
G_store (s) *copy string to allocated memory*

This routine allocates enough memory to hold the string **s**, copies **s** to the allocated memory, and returns a pointer to the allocated memory.

These 2 routines convert between upper and lower case.

G_tolcase (s) *convert string to lower case*

char *s;

Upper case letters in the string **s** are converted to their lower case equivalent. Returns **s**.

G_toucase (s) *convert string to upper case*

char *s;

Lower case letters in the string **s** are converted to their upper case equivalent. Returns **s**.

And finally a routine which gives a printable version of control characters.

char *
G_unctrl (c) *printable version of control character*

unsigned char c;

This routine returns a pointer to a string which contains an English-like representation for the character **c**. This is useful for non-printing characters, such as control characters. Control characters are represented by ctrl-c, e.g., control A is represented by ctrl-A. 0177 is represented by DEL/RUB. Normal characters remain unchanged.

This routine is useful in combination with *G_intr_char(p.117)* for printing the user's interrupt character:

```
char G_intr_char( );
char *G_unctrl( );

printf("Your interrupt character is %s\n", G_unctrl(G_intr_char( )));
```

Note. G_unctrl( ) uses a hidden static buffer which is overwritten from call to call.

12.15. Enhanced UNIX Routines

A number of useful UNIX library routines have side effects which are sometimes undesirable. The routines here provide the same functions as their corresponding UNIX routine, but with different side effects.

12.15.1. Running in the Background

The standard UNIX fork( ) routine creates a child process which is a copy of the parent process. The fork( ) routine is useful for placing a program into the background. For example, a program that gathers input from the user interactively, but knows that the processing will take a long time, might want to run in the background after gathering all the input. It would fork( ) to create a child process, the parent would exit( ) allowing the child to continue in the background, and the user could then do other processing.

However, there is a subtle problem with this logic. The fork( ) routine does not protect child processes from keyboard interrupts even if the parent is no longer running. Keyboard interrupts will also kill background processes that don't protect themselves.[33] Thus a program which puts itself in the background may never finish if the user interrupts another program which is running at the keyboard.

The solution is to fork( ) but also put the child process in a process group which is different from the keyboard process group. G_fork( ) does this.

[33] Programmers who use /bin/sh know that programs run in the background (using & on the command line) are not automatically protected from keyboard interrupts. To protect a command that is run in the background, /bin/sh users must do **nohup** *command*&. Programmers who use the /bin/csh (or other variants) do not know, or forget that the C-shell automatically protects background processes from keyboard interrupts.

G_fork ( ) *create a protected child process*

This routine creates a child process by calling the UNIX fork( ) routine. It also changes the process group for the child so that interrupts from the keyboard do not reach the child. It does not cause the parent to exit( ).

G_fork( ) returns what fork( ) returns: -1 if fork( ) failed; otherwise 0 to the child, and the process id of the new child to the parent.

Note. Interrupts are still active for the child. Interrupts sent using the *kill* command, for example, will interrupt the child. It is simply that keyboard-generated interrupts are not sent to the child.

12.15.2. Partially Interruptible System Call

The UNIX system( ) call allows one program, the parent, to execute another UNIX command or program as a child process, wait for that process to complete, and then continue. The problem addressed here concerns interrupts. During the standard system( ) call, the child process inherits its responses to interrupts from the parent. This means that if the parent is ignoring interrupts, the child will ignore them as well. If the parent is terminated by an interrupt, the child will be also.

However, in some cases, this may not be the desired effect. In a menu environment where the parent activates menu choices by running commands using the system( ) call, it would be nice if the user could interrupt the command, but not terminate the menu program itself. The G_system( ) call allows this.

G_system (command) *run a shell level command*

The shell level **command** is executed. Interrupt signals for the parent program are ignored during the call. Interrupt signals for the **command** are enabled. The interrupt signals for the parent are restored to their previous settings upon return.

G_system( ) returns the same value as system( ), which is essentially the exit status of the **command**. See UNIX manual system(1) for details.

12.16. Miscellaneous

A number of general purpose routines have been provided.

char *
G_date ( ) *current date and time*

Returns a pointer to a string which is the current date and time. The format is the same as that produced by the UNIX *date* command.

G_gets (buf) *get a line of input (detect ctrl-z)*

char *buf;

This routine does a *gets* ( ) from stdin into **buf.** It exits if end-of-file is detected. If stdin is a tty (i.e., not a pipe or redirected) then ctrl-z is detected.

Returns 1 if the read was successful, or 0 if ctrl-z was entered.

Note. This is very useful for allowing a program to reprompt when a program is restarted after being stopped with a ctrl-z. If this routine returns 0, then the calling program should re-print a prompt and call *G_gets* ( ) again. For example:

```
char buf[1024];

do {
    printf("Enter some input: ") ;
} while ( ! G_gets(buf) ) ;
```

char *
G_home ( ) *user's home directory*

Returns a pointer to a string which is the full path name of the user's home directory.

char
G_intr_char ( ) *return interrupt char*

This routine returns the user's keyboard interrupt character. This is the character that generates the SIGINT signal from the keyboard.

See also *G_unctrl(p. 114)* for converting this character to a printable format.

G_percent (n, total, incr) *print percent complete messages*

int n;
int total;
int incr;

This routine prints a percentage complete message to stderr. The percentage complete is (**n/ total**)*100, and these are printed only for each **incr** percentage. This is perhaps best explained by example:

```
#include <stdio.h>
int row;
int nrows;

nrows = 1352;   /* 1352 is not a special value - example only */
fprintf (stderr, "Percent complete: ");
for (row = 0; row < nrows; row++)
    G_percent (row, nrows, 10);
```

This will print completion messages at 10% increments; i.e., 10%, 20%, 30%, etc., up to 100%. Each message does not appear on a new line, but rather erases the previous message. After 100%, a new line is printed.

char *
G_program_name ( ) *return program name*

This routine returns the name of the program as set by the call to *G_gisinit(p. 64)*.

char *
G_whoami ( ) *user's name*

Returns a pointer to a string which is the user's login name.

G_yes (question, default) *ask a yes/no question*

```
char *question;
int default;
```

This routine prints a **question** to the user, and expects the user to respond either yes or no. (Invalid responses are rejected and the process is repeated until the user answers yes or no.)

The **default** indicates what the RETURN key alone should mean. A **default** of 1 indicates that RETURN means yes, 0 indicates that RETURN means no, and -1 indicates that RETURN alone is not a valid response.

The **question** will be appended with "(y/n) ", and, if **default** is not -1, with "[y] " or "[n] ", depending on the **default**.

G_yes ( ) returns 1 if the user said yes, and 0 if the user said no.

12.17. GIS Library Data Structures

Some of the data structures, defined in the "gis.h" header file and used by routines in this library, are described in the sections below.

12.17.1. struct Cell_head

The cell header data structure is used for two purposes. It is used for cell header information for map layers. It also used to hold window values. The structure is:

```
struct Cell_head
{
        int format;          /*   number of bytes per cell              */
        int compressed;      /*   compressed(1) or not compressed(0)    */
        int rows, cols;      /*   number of rows and columns            */
        int proj;            /*   projection                            */
        int zone;            /*   zone                                  */
        double ew_res;       /*   east-west resolution                  */
        double ns_res;       /*   north-south resolution                */
        double north;        /*   northern edge                         */
        double south;        /*   southern edge                         */
        double east;         /*   eastern edge                          */
        double west;         /*   western edge                          */

};
```

The *format* and *compressed* fields apply only to cell headers. The *format* field describes the number of bytes per cell data value and the *compressed* field indicates if the cell file is compressed or not. The other fields apply both to cell headers and windows. The geographic boundaries are described by *north, south, east* and *west.* The grid resolution is described by *ew_res* and *ns_res*. The cartographic projection is described by *proj* and the related zone for the projection by *zone*. The *rows* and *cols* indicate the number of rows and columns in the cell file, or in the window. See §*5.3 Cell Header Format* [*p.26*] for more information about cell headers, and §*9.1 Window* [*p.47*] for more information about windows.

The routines described in §*12.9.1 Cell Header File* [*p.89*] use this structure.

12.17.2. struct Categories

The category data structure contains map layer title and category labels. It is used both for cell files and vector files. The structure is:

```
struct Categories
{
        CELL num;       /*  total number of categories            */
        char *title;    /*  name of data layer                    */
        char *fmt;      /*  printf-like format to generate labels */
        float m1;       /*  multiplication coefficient 1          */
        float a1;       /*  addition coefficient 1                */
        float m2;       /*  multiplication coefficient 2          */
        float a2;       /*  addition coefficient 2                */
        struct Cat_List
        {
          CELL num;     /*  category number                       */
          char *label;  /*  category label                        */
        } *list;
        int count;      /*  number of labels allocated            */

};
```

The Categories structure contains a *title* for the map layer, the largest category in the map layer (*num*), an automatic label generation rule for missing labels (*fmt, m1, a1, m2, a2*), and a *list* of category labels for *count* specific categories.

This structure should be accessed using the routines described in §*12.9.2 Cell Category File* [*p.91*].

12.17.3. struct Colors

The color data structure holds red, green, and blue color intensitics for cell categories. The structure is:

```
struct Colors
{
        CELL min,max;      /*  min,max color numbers   */
        uchar *red;        /*  red, green, blue (0-255) */
        uchar *grn;        /*    allocated as needed   */
        uchar *blu;
        uchar r0,g0,b0;    /*  red, green, blue for cat 0  */

};
```

Except for category zero, the color intensities are stored in the (unsigned char) arrays *red, grn,* and *blu.* The minimum and maximum categories which have colors are *min* and *max.*

The routines described in §*12.9.3 Cell Color Table* [*p.94*] use this structure.

The routine *G_get_color*(*p.95*) should be used to get individual colors from the structure. However, for completeness, to find the colors for category *n:*

```
if (n != 0 && n >= min && n <= max)
{
        red[n-min]
        grn[n-min]
        blu[n-min]
}
```

The color for category zero is represented by *r0, g0* and *b0.*

12.17.4. struct History

The *History* structure is used to document cell files. The information contained here is for the user. It is not used in any operational way by GRASS. The structure is:

```
#define MAXEDLINES  25
#define RECORD_LEN  80

struct History
{
        char mapid[RECORD_LEN];
        char title[RECORD_LEN];
        char mapset[RECORD_LEN];
        char creator[RECORD_LEN];
        char maptype[RECORD_LEN];
        char datsrc_1[RECORD_LEN];
        char datsrc_2[RECORD_LEN];
        char keywrd[RECORD_LEN];
        int  edlinecnt;
        char edhist[MAXEDLINES][RECORD_LEN];

};
```

The *mapid* and *mapset* are the cell file name and mapset, *title* is the cell file title, *creator* is the user who created the file, *maptype* is the map type (which should always be "cell"), *datasrc_1* and *datasrc_2* describe the original data source, *keyword* is a one-line data description and *edhist* contains *edlinecnt* lines of user comments.

The routines described in §*12.9.4 Cell History File* [p.98] use this structure. However, there is very little support for manipulating the contents of this structure. The programmer must manipulate the contents directly.

Note. Some of the information in this structure is not meaningful. For example, if the cell file is renamed, or copied into another mapset, the *mapid* and *mapset* will no longer be correct. Also the *title* does not reflect the true cell file title. The true title is maintained in the category file.

Warning. This structure has remained unchanged since the inception of GRASS. There is a good possibility that it will be changed or eliminated in future releases.

12.17.5. struct Range

The *Range* structure contains the minimum and maximum values which occur in a cell file. The structure is:

```
struct Range
{
        CELL nmin;    /*   min negative    */
        CELL nmax;    /*   max negative    */
        CELL pmin;    /*   min positive    */
        CELL pmax;    /*   max posivive    */

};
```

Note that the range is divided into positive and negative ranges. The positive range is represented by *pmin* and *pmax,* and the negative range by *nmin* and *nmax.* If there are no negative values in the cell file, then both *nmin* and *nmax* will be zero. Also if there are no positive values in the file, then both *pmin* and *pmax* will be zero.

The following idiomatic expression is used to determine the full data range:

```
min = nmin ? nmin : pmin ;
max = pmax ? pmax : nmax ;
```

The routines described in §*12.9.5 Cell Range File* [*p.99*] use this structure.

12.18. Loading the GIS Library

The library is loaded by specifying $(GISLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(GISLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(GISLIB)

$(GISLIB): # in case the library changes
```

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

Chapter 13

Dig Library

13.1. Introduction

The *Dig Library* provides the GRASS programmer with routines to process the binary *dig* vector files. It is assumed that the reader has read §*4 Database Structure* [*p.15*] for a general description of GRASS databases, and §*6 Vector Maps* [*p.31*] for details about vector files in GRASS.

The routines in the *Dig Library* are presented in functional groupings, rather than in alphabetical order. The order of presentation will, it is hoped, provide a better understanding of how the library is to be used, as well as show the inter-relationships among the various routines. Note that a good way to understand how to use these routines is to look at the source code for GRASS programs which use them.[1]

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **dig_**.[2] To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix D. Index to Dig Library* [*p.243*].

13.1.1. Include Files

The following files contain definitions and structures required by some of the routines in this library. The programmer should therefore include these files in code that uses this library:[3]

[1] Some of these programs are *a.b.vect, b.a.vect, vect.to.cell, Dvect, Gpoly, Pmap,* and *Vpatch.*

[2] **Warning.** There are also 6 additional global variables and/or routines which do NOT begin with this prefix: *debugf, head, sample_thresh, Lines_In_Memory, Mem_Line_Ptr,* and *Mem_curr_position.*

[3] The GRASS compilation process, described in §*11 Compiling GRASS Programs Using Gmake* [*p.55*], automatically tells the C compiler how to find this and other GRASS header files.

```
#include "dig_defines.h"
#include "dig_structs.h"
```

13.1.2. Vector Arc Types

A complete discussion of GRASS vector terminology can be found in §*6.1 What is a Vector Map Layer?* [*p.31*] and the reader should review that section. Briefly, vector data is stored as arcs representing linear, area, or point[4] features. These arc types are coded as LINE, AREA, and DOT respectively, (and are #defined in the file "dig_defines.h").

13.1.3. Levels of Access

There are two levels of read access to these vector files:

Level One provides simple access to the arc information contained in the vector files. There is no access to category or topology information at this level.

Level Two provides full access to all the information contained in the vector file and its support files, including line, category, node, and area information. This level requires more from the programmer, more memory, and longer startup time.

Note. The routines in this library which process *arcs* are named using the word *line*. They should be named using the word *arc* instead. Since that would require modifying a lot of existing code, the names have not been changed.

13.2. Level One Read Access

Level One access allows the reading of arcs from a vector file. Most of the routines require a file descriptor **fd** open to read a vector file, as returned by *G_fopen_vector_old*(*p. 103*).

13.2.1. Initialization/Termination

The following routines perform initialization and termination actions for *Level One*

[4] Point data in vector files is not supported under GRASS 3.0, but there are plans to support it in later versions. The routines in this library are written with this upgrade in mind.

vector access:

dig_init (fd) *initialize level one vector access*

FILE *fd;

Initialize for *Level One* access. The file descriptor **fd** is rewound, the header information is extracted and stored away, and **fd** is positioned to read the first arc in the file.

Returns 0 if ok, or a negative value if error.

Note. This routine MUST be called before using any other *Level One* routines.

dig_rewind (fd) *rewind vector file*

FILE *fd;

The file descriptor **fd** is rewound, the header information is extracted and stored away, and **fd** is positioned to read the first arc in the file.

Note. This routine is the same as *dig_init*(*p. 125*).

Returns 0 if ok, or a negative value on error.

dig_print_header ( ) *display vector header information*

After calling *dig_init*(*p. 125*), selected information from the vector file header can be printed to stdout using this routine.

Return value is undefined.

Warning. It is permissible to have more than one vector file open for *Level One* access. However, this routine prints the header information extracted by the previous call to either *dig_init*(*p. 125*) or *dig_rewind*(*p. 125*).

dig_fini (fd) *end level one vector access*

FILE *fd;

Terminate *Level One* access. To be called when finished accessing the vector file with *Level One* routines.

Return value is undefined.

Note. This routine does not close the file descriptor **fd**. Use *fclose* ( ) to close the file descriptor.

13.2.2. Reading Arcs

The next routines read arcs sequentially from the vector file.

dig_read_next_line (fd, np, x, y) *get next arc*

```
FILE *fd;
int *np;
double **x, **y;
```

The points constituting the next arc in the vector file open on **fd** are read into hidden arrays. Pointers to these arrays are placed in **x** and **y**, and **np** is set to the number of points in the arc.

Returns the arc type: LINE or AREA (as defined in "dig_defines.h"), or -2 if no more arcs, or -1 on error.

Note. The DOT type is skipped by this routine.

Note. The programmer must pass **x** and **y** as addresses of pointers. For example:

```
FILE *fd;
int np;
double *x, *y;

dig_read_next_line (fd, &np, &x, &y);
```

dig_read_next_line_type (fd, np, x, y, type) *get next arc by type*

```
FILE *fd;
int *np;
double **x, **y;
int type;
```

Same as *dig_read_next_line(p. 126)* except that it limits the search to the specified **type**, which can be any combination of LINE, AREA, or DOT.

For example, to read the next LINE or AREA:

```
FILE *fd;
int np;
double *x, *y;

dig_read_next_line_type (fd, &np, &x, &y, LINE | AREA);
```

Returns the arc type: LINE, AREA or DOT (as defined in "dig_defines.h"), or -2 if no more arcs, or -1 on error.

dig_init_box (N, S, E, W) *limit arc search in box*

double N, S, E, W;

Define a window within which to search for arcs using *dig_read_line_in_box(p. 127)*. This allows the programmer to limit the arcs retrieved to those within the window specified by **N** (north), **S** (south), **E** (east), and **W** (west).

The window must have **N** > **S**, and **E** > **W**.

Returns 0 if window is valid, or negative on error.

Note. This routine does NOT change the position of the file pointer. In particular, it does not rewind the file.

dig_read_line_in_box (fd, np, x, y) *read arc in box*

FILE *fd;
int *np;
double **x, **y;

Same as *dig_read_next_line(p. 126)* except that it only looks inside the bounding box set by *dig_init_box(p. 127)*.

Note. This routine only ignores arcs which are completely outside the bounding box. If any part of the arc falls within the bounding box, the entire arc is read, including the parts outside the box. No clipping is performed.

13.3. Level Two Read Access

This level provides full access to all the information contained in the vector file and its support files. Arc, area, and node information is available, including the internal indexes for each entity, as well as category attributes.

The indexes are unique, and can be used to distinguish one area from another, or one arc from another. Note, however, that different areas may have the same category attribute (as may different arcs).

13.3.1. Initialization/Termination

The following routines perform initialization and termination actions for *Level Two* vector access:

dig_P_init (name, mapset, map) *initialize level two vector access*

```
char *name;
char *mapset;
struct Map_info *map;
```

Initialize *Level Two* read access to vector file **name** in **mapset**. This routine opens any files it will need.

Return value is undefined. This routine will exit on any error and print a description of the error.

Note. This routine MUST be called before calling any other *Level Two* routines.

dig_P_fini (map) *end level two vector access*

```
struct Map_info *map;
```

Terminate *Level Two* access for **map**. This routine closes any files opened by *dig_P_init*(p. 128).

dig_P_tmp_close (map) *temporary close vector map*

```
struct Map_info *map;
```

Temporarily close access to **map**. This is useful to free one open file while not needed.

Return is undefined.

dig_P_tmp_open (map) *reopen closed vector map*

```
struct Map_info *map;
```

Reopen a **map** that has been closed with *dig_P_tmp_close*(p. 128).

Return value is undefined. If map->digit == NULL, then the call failed.

13.3.2. Area Retrieval

The following routines retrieve area information.

dig_P_num_areas (map) *get number of areas*

```
struct Map_info *map;
```

Return total number of areas in the vector **map.**

Note. The area indexes are numbered from 1 to *n*, where *n* is the number of areas in the vector file, as returned by this routine.

dig_P_get_area_xy (map, n, np, x, y) *get area polygon*

```
struct Map_info *map;
int n;
int *np;
double **x, **y;
```

Given area index **n,** all the points for the area are read into hidden arrays. Pointers to these arrays are placed in **x** and **y.** Points are in clockwise order. The pointers **x** and **y** are valid until the next call to this routine.

Returns 0 if found, or negative on error.

Note. The programmer must pass **x** and **y** as addresses of pointers:

```
struct Map_info map;
int n, np;
double *x, *y;

dig_P_get_area_xy (&map, n, &np, &x, &y);
```

dig_P_get_area (map, n, pa) *get area polygon*

```
struct Map_info *map;
int n;
P_AREA **pa;
```

Given area index **n,** the *P_AREA* information for the area is read into a hidden structure. A pointer to this structure is placed in **pa.** The pointer **pa** is valid until the next call to this routine.

Returns 0 if found, or negative on error.

dig_P_area_att (map, n) *get area category attribute*

```
struct Map_info *map;
int n;
```

Given area index **n**, return its category number.

Returns 0 if not an area or if unlabeled.

dig_P_get_area_bbox (map, n, N, S, E, W) *get area bounding box*

```
struct Map_info *map;
int n;
double *N, *S, *E, *W;
```

Given area index **n**, set **N** (north), **S** (south), **E** (east), and **W** (west) to the values of the bounding box for the area.

Returns 0 if ok, or -1 on error.

13.3.3. Arc Retrieval

The following routines retrieve arc information.

dig_P_num_lines (map) *get number of arcs*

```
struct Map_info *map;
```

Returns total number of arcs in the vector **map**.

Note. The arc indexes are numbered from 1 to *n*, where *n* is the number of arcs in the vector file, as returned by this routine.

dig_P_read_line (map, n, p) *read arc*

```
struct Map_info *map;
int n;
struct line_pnts **p;
```

Given arc index **n**, the points for the arc are read into a hidden *line_pnts* structure. A pointer to this structure is placed in **p**. The pointer **p** is valid until the next call to this routine or to *dig_P_read_next_line*(*p. 131*).

Returns the same values as *dig_read_next_line*(*p. 126*).

dig_P_read_next_line (map, p) *read next arc*

```
struct Map_info *map;
struct line_pnts **p;
```

The points for the next arc in the vector **map** are read into a hidden *line_pnts* structure. A pointer to this structure is placed in **p**. The pointer **p** is valid until the next call to this routine or to *dig_P_read_line*(*p. 130*).

Returns the same values as *dig_read_next_line*(*p. 126*).

dig_P_rewind (map) *rewind next-arc pointer*

```
struct Map_info *map;
```

Resets the next-arc pointer to beginning of list. For use with *dig_P_read_next_line*(*p. 131*).

Return is undefined.

dig_P_line_att (map, n) *get arc category attribute*

```
struct Map_info *map;
int n;
```

Given arc index **n**, return its category number.

Returns 0 if not labeled or on error.

dig_P_get_line_bbox (map, n, N, S, E, W) *get arc bounding box*

```
struct Map_info *map;
int n;
double *N, *S, *E, *W;
```

Given arc index **n**, set **N** (north), **S** (south), **E** (east), and **W** (west) to the values of the bounding box for the arc.

Returns 0 if ok, or negative on error.

13.3.4. Area Analysis Tools

The following routines provide some area-related analyses.

dig_point_to_area (map, x, y) *find area with point*

```
struct Map_info *map;
double x, y;
```

Returns the index of the area containing the point **x,y**, or 0 if none found.

double
dig_point_in_area (map, x, y, pa) *point in area*

```
struct Map_info *map;
double x, y;
P_AREA *pa;
```

Given a filled *P_AREA* structure **pa**, determines if **x,y** is within the area. The structure **pa** can be filled with *dig_P_get_area(p. 129)*.

Returns 0.0 if **x,y** is not in the area, the positive minimum distance to the nearest area edge if **x,y** is inside the area, or -1.0 on error.

13.3.5. Arc Analysis Tools

The following routines provide some arc-related analyses.

dig_point_to_line (map, x, y, type) *find arc with point*

```
struct Map_info *map;
double x, y;
char type;
```

Returns the index of the arc which is nearest to the point **x,y**. The point **x,y** must be within the arc's bounding box. Set **type** to a combination of LINE, AREA or DOT (e.g., LINE | AREA), or (char)-1 if you want to search all arc types.

dig_check_dist (map, n, x, y, d) *distance to arc*

```
struct Map_info *map;
int n;
double x, y;
double *d;
```

Computes **d**, the square of the minimum distance from point **x,y** to arc **n**.

Returns the number of the segment that was closest, or -1 on error. The segment number, in combination with *dig_P_read_line(p. 130)* can be used to determine the end-points of the closest line-segment in the arc:

```
struct Map_info map;
double x,y,d;
double x1,y1,x2,y2;
int n;
struct line_pnts *p;

if ((s = dig_check_dist(&map, n, x, y, &d)) > 0)
{
            dig_P_read_line (&map, n, &p);
            x1 = p->x[s-1];
            y1 = p->y[s-1];
            x2 = p->x[s];
            y2 = p->y[s];
}
```

13.4. Writing Binary Dig files

The following routines are provided for import and export capabilities.

Note. The file descriptors required by these routines should be either open for writing, or for reading, but not for both writing and reading.

long
dig_Write_line (fd, type, x, y, np) *write arc*

```
FILE *fd;
char type;
double *x, *y;
int np;
```

Writes the arc, defined by the **np** points in the **x** and **y** arrays, to the end of the binary *dig* vector file open on file descriptor **fd**. The arc **type** must be one of LINE, AREA, or DOT.

Returns the *offset* in the file where the arc was written. This *offset* can be used with *dig_Read_line*(*p. 133*).

dig_Read_line (fd, offset, x, y, np) *read arc*

```
FILE *fd;
long offset;
double **x, **y;
int *np;
```

Seeks to the specified **offset** on file descriptor **fd** and reads the arc which begins there into hidden arrays. Pointers to these arrays are then placed into **x** and **y** and **np** is set to the number of points in the arc.

Return is the same as *dig_read_next_line*(*p. 126*) from *Level One*.

Note. The programmer must pass **x** and **y** as addresses of pointers:

```
FILE *fd;
long offset;
int np;
double *x, *y;

dig_Read_line (fd, offset, &x, &y, &np);
```

dig_read_head_binary (fd, header) *read vector header*

```
FILE *fd;
struct dig_head *header;
```

Reads the **header** from the binary *dig* vector file open on file descriptor **fd**. It can be used to position **fd** ready to read the first arc in the file.

Currently only returns 0.

Note. If using *Level One* routines, it is unnecessary to call this routine.

dig_write_head_binary (fd, header) *write vector header*

```
FILE *fd;
struct dig_head *header;
```

Writes the **header** information to the binary *dig* vector file open on file descriptor **fd**. This routine must be the first to write to a new vector file. After the **header** has been written, arcs can be sequentially written to the file. It can also be used to rewrite the header information after the entire file has been written, if necessary.

Currently only returns 0.

13.5. Miscellaneous Tools

double
dig_distance2_point_to_line (x, y, x1, y1, x2, y2) *distance to line-segment*

```
double x, y;
double x1, y1, x2, y2;
```

Computes the square of the minimum distance from point **x,y** to the line-segment **x1,y1,x2,y2.**

Returns the distance squared.

double
dig_xy_distance2_point_to_line (x,y,x1,y1,x2,y2) *distance to line-segment*

    double *x, *y;
    double x1, y1, x2, y2;

Returns the square of the minimum distance from point **x,y** to the line-segment **x1,y1,x2,y2.**

Changes **x,y** to the point on the segment **x1,y1,x2,y2** which is closest to **x,y.**

dig_prune (p, threshold) *prune a dense arc*

    struct line_pnts *p;
    double threshold;

Given a filled *line_pnts* structure **p,** prune it within the specified **threshold.** This function is used to reduce the number of points needed to define an arc within a given accuracy.

Returns the new number of points.

dig_bound_box (p, N, S, E, W) *get arc bounding box*

    struct line_pnts *p;
    double *N, *S, *E, *W;

Given a filled *line_pnts* structure **p** containing a list of X,Y coordinates, compute the bounding box of this list.

Returns non-zero on error.

13.6. Loading the Dig Library

The library is loaded by specifying $(DIGLIB)[5] in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

[5] This variable was NOT defined in releases 3.0 and 3.0A. Edit the file *$GISBASE/src/CMD/make.mid* and add the line: **DIGLIB=$(SRC)/mapdev/lib/diglib.a** at the bottom of the file.

Gmakefile for $(DIGLIB)

```
OBJ = main.o sub1.o sub2.o
EXTRA_CFLAGS = -I$(SRC)/mapdev/lib

pgm: $(OBJ) $(DIGLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(DIGLIB)

$(DIGLIB): # in case the library changes
```

Note. EXTRA_CFLAGS tells the C compiler where additional #include files are located. This is necessary since the required #include files do not live in the normal GRASS #include directory.

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

Chapter 14

Imagery Library

14.1. Introduction

The *Imagery Library* was created for version 3.0 of GRASS to support integrated image processing directly in GRASS. It contains routines that provide access to the *group* database structure which was also introduced in GRASS 3.0 for the same purpose.[1]

It is assumed that the reader has read §*4 Database Structure* [*p. 15*] for a general description of GRASS databases, §*8 Image Data: Groups* [*p. 41*] for a description of imagery groups, and §*5 Grid Cell Maps* [*p. 23*] for details about map layers in GRASS.

The routines in the *Imagery Library* are presented in functional groupings, rather than in alphabetical order. The order of presentation will, it is hoped, provide a better understanding of how the library is to be used, as well as show the inter-relationships among the various routines. Note that a good way to understand how to use these routines is to look at the source code for GRASS programs which use them.[2]

Most routines in this library require that the header file "imagery.h" be included in any code using these routines.[3] Therefore, programmers should always include this file when writing code using routines from this library:

```
#include "imagery.h"
```

This header file includes the "gis.h" header file as well.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix I_. To avoid name conflicts, programmers should not create

[1] Since this is a new library, it is expected to grow. Hopefully, image analysis functions will be added to complement the database functions already in the library.

[2] See §*8.4 Imagery Programs* [*p. 45*] for a list of some imagery programs.

[3] The GRASS compilation process, described in §*11 Compiling GRASS Programs Using Gmake* [*p. 55*], automatically tells the C compiler how to find this and other GRASS header files.

variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix E. Index to Imagery Library* [*p.245*].

14.2. Group Processing

The group is the key database structure which permits integration of image processing in GRASS.

14.2.1. Prompting for a Group

The following routines interactively prompt the user for a group name in the current mapset.[4] In each, the **prompt** string will be printed as the first line of the full prompt which asks the user to enter a group name. If **prompt** is the empty string "", then an appropriate prompt will be substituted. The name that the user enters is copied into the **group** buffer.[5] These routines have a built-in 'list' capability which allows the user to get a list of existing groups.

The user is required to enter a valid group name, or else hit the RETURN key to cancel the request. If the user enters an invalid response, a message is printed, and the user is prompted again. If the user cancels the request, 0 is returned; otherwise, 1 is returned.

I_ask_group_old (prompt, group) *prompt for an existing group*

    char *prompt;
    char *group;

Asks the user to enter the name of an existing **group** in the current mapset.

I_ask_group_new (prompt, group) *prompt for new group*

    char *prompt;
    char *group;

Asks the user to enter a name for a **group** which does not exist in the current mapset.

[4] This library only works with groups in the current mapset. Other mapsets, even those in the user's mapset search path, are ignored.

[5] The size of **group** should be large enough to hold any GRASS file name. Most systems allow file names to be quite long. It is recommended that name be declared *char group[50]*.

I_ask_group_any (prompt, group) *prompt for any valid group name*

char *prompt;
char *group;

Asks the user to enter a valid **group** name. The **group** may or may not exist in the current mapset.

Note. The user is not warned if the **group** exists. The programmer should use *I_find_group*(*p. 139*) to determine if the **group** exists.

Here is an example of how to use these routines. Note that the programmer must handle the 0 return properly:

```
char group[50];

if ( ! I_ask_group_any ("Enter group to be processed", group))
    exit(0);
```

14.2.2. Finding Groups in the Database

Sometimes it is necessary to determine if a given group already exists. The following routine provides this service:

I_find_group (group) *does group exist?*

char *group;

Returns 1 if the specified **group** exists in the current mapset; 0 otherwise.

14.2.3. REF File

These routines provide access to the information contained in the REF file for groups and subgroups, as well as routines to update this information. They use the *Ref* structure, which is defined in the "imagery.h" header file; see §*14.4 Imagery Library Data Structures* [*p. 144*].

The contents of the REF file are read or updated by the following routines:

I_get_group_ref (group, ref) *read group REF file*

```
char *group;
struct Ref *ref;
```

Reads the contents of the REF file for the specified **group** into the **ref** structure.

Returns 1 if successful; 0 otherwise (but no error messages are printed).

I_put_group_ref (group, ref) *write group REF file*

```
char *group;
struct Ref *ref;
```

Writes the contents of the **ref** structure to the REF file for the specified **group**.

Returns 1 if successful; 0 otherwise (and prints a diagnostic error).

Note. This routine will create the **group**, if it doesn't already exist.

I_get_subgroup_ref (group, subgroup, ref) *read subgroup REF file*

```
char *group;
char *subgroup;
struct Ref *ref;
```

Reads the contents of the REF file for the specified **subgroup** of the specified **group** into the **ref** structure.

Returns 1 if successful; 0 otherwise (but no error messages are printed).

I_put_subgroup_ref (group, subgroup, ref) *write subgroup REF file*

```
char *group;
char *subgroup;
struct Ref *ref;
```

Writes the contents of the **ref** structure into the REF file for the specified **subgroup** of the specified **group**.

Returns 1 if successful; 0 otherwise (and prints a diagnostic error).

Note. This routine will create the **subgroup**, if it doesn't already exist.

These next routines manipulate the *Ref* structure:

I_init_group_ref (ref) *initialize Ref structure*

struct Ref *ref;

This routine initializes the **ref** structure for other library calls which require a *Ref* structure. This routine must be called before any use of the structure can be made.

Note. The routines *I_get_group_ref*(*p. 140*) and *I_get_subgroup_ref*(*p. 140*) call this routine automatically.

I_add_file_to_group_ref (name, mapset, ref) *add file name to Ref structure*

char *name;
char *mapset;
struct Ref *ref;

This routine adds the file **name** and **mapset** to the list contained in the **ref** structure, if it isn't already in the list. The **ref** structure must have been properly initialized.

This routine is used by programs, such as *i.maxlik*, to add to the group new cell files created from files already in the group.

Returns the index into the *file* array within the **ref** structure for the file after insertion; see §*14.4 Imagery Library Data Structures* [*p. 144*].

I_transfer_group_ref_file (src, n, dst) *copy Ref lists*

struct Ref *src;
int n;
struct Ref *dst;

This routine is used to copy file names from one *Ref* structure to another. The name and mapset for file **n** from the **src** structure are copied into the **dst** structure (which must be properly initialized).

For example, the following code copies one *Ref* structure to another:

```
struct Ref src,dst;
int n;

/* some code to get information into src */

   .
   .
I_init_group_ref (&dst);
for (n = 0; n < src.nfiles; n++)
    I_transfer_group_ref_file (&src, n, &dst);
```

This routine is used by *i.points* to create the REF file for a subgroup.

I_free_group_ref (ref) *free Ref structure*

    struct Ref *ref;

This routine frees memory allocated to the **ref** structure.

14.2.4. TARGET File

The following two routines read and write the TARGET file.

I_get_target (group, location, mapset) *read target information*

    char *group;
    char *location;
    char *mapset;

Reads the target **location** and **mapset** from the TARGET file for the specified **group**.

Returns 1 if successful; 0 otherwise (and prints a diagnostic error).

This routine is used by *i.points* and *i.rectify* and probably shouldn't be used by other programs.

Note. This routine does **not** validate the target information.

I_put_target (group, location, mapset) *write target information*

    char *group;
    char *location;
    char *mapset;

Writes the target **location** and **mapset** to the TARGET file for the specified **group**.

Returns 1 if successful; 0 otherwise (but no error messages are printed).

This routine is used by *i.target* and probably shouldn't be used by other programs.

Note. This routine does **not** validate the target information.

14.2.5. POINTS File

The following routines read and write the POINTS file, which contains the image registration control points. This file is created and updated by the program *i.points*, and read by *i.rectify*.

These routines use the *Control_Points* structure, which is defined in the "imagery.h" header file; see §*14.4 Imagery Library Data Structures* [*p. 144*].

Note. The interface to the *Control_Points* structure provided by the routines below is incomplete. A routine to initialize the structure is needed.

I_get_control_points (group, cp) *read group control points*

```
char *group;
struct Control_Points *cp;
```

Reads the control points from the POINTS file for the **group** into the **cp** structure.

Returns 1 if successful; 0 otherwise (and prints a diagnostic error).

Note. An error message is printed if the POINTS file is invalid, or doesn't exist.

I_new_control_point (cp, e1, n1, e2, n2, status) *add new control point*

```
struct Control_Points *cp;
double e1, n1;
double e2, n2;
int status;
```

Once the control points have been read into the **cp** structure, this routine adds new points to it. The new control point is given by **e1** (column) and **n1** (row) on the image, and the **e2** (east) and **n2** (north) for the target database. The value of **status** should be 1 if the point is a valid point; 0 otherwise.[6]

[6] Use of this routine implies that the point is probably good, so **status** should be set to 1.

I_put_control_points (group, cp) *write group control points*

```
char *group;
struct Control_Points *cp;
```

Writes the control points from the **cp** structure to the POINTS file for the specified **group**.

Note. Points in **cp** with a negative *status* are not written to the POINTS file.

14.3. Loading the Imagery Library

The library is loaded by specifying $(IMAGERYLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(IMAGERYLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(IMAGERYLIB) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(IMAGERYLIB) $(GISLIB)

$(IMAGERYLIB):                    # in case the library changes
$(GISLIB):                        # in case the library changes
```

Note. This library must be loaded with $(GISLIB) since it uses routines from that library. See §*12 GIS Library* [*p.63*] for details on that library.

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

14.4. Imagery Library Data Structures

Some of the data structures in the "imagery.h" header file are described below.

14.4.1. struct Ref

The *Ref* structure is used to hold the information from the REF file for groups and subgroups. The structure is:

```
struct Ref
{
        int nfiles;                  /*    number of REF files              */
        struct Ref_Files
        {
           char name[30];            /*    REF file name                    */
           char mapset[30];          /*    REF file mapset                  */
        } *file;
        struct Ref_Color
        {
           unsigned char *table;     /*    color table for min-max values   */
           unsigned char *index;     /*    data translation index           */
           unsigned char *buf;       /*    data buffer for reading color file */
           int fd;                   /*    for image i/o                    */
           CELL min, max;            /*    min,max CELL values              */
           int n;                    /*    index into Ref_Files             */
        } red, grn, blu;
} ;
```

The *Ref* structure has *nfiles* (the number of cell files), *file* (the name and mapset of each file), and *red,grn,blu* (color information for the group or subgroup[7]).

There is no function interface to the *nfiles* and *file* elements in the structure. This means that the programmer must reference the elements of the structure directly.[8] The name and mapset for the *i* th file are *file[i].name*, and *file[i].mapset*.

For example, to print out the names of the cell files in the structure:

```
int i;
struct Ref ref;

      .
      .
      .

/* some code to get the REF file for a group into ref */

      .
      .
      .

for (i = 0; i < ref.nfiles; i++)
   printf ("%s in %s\n", ref.file[i].name, ref.file[i].mapset);
```

14.4.2. struct Control_Points

The *Control_Points* structure is used to hold the control points from the group POINTS file. The structure is:

[7] The *red,grn,blu* elements are expected to change as the imagery code develops. Do **not** reference them. Pretend they don't exist.

[8] The *nfiles* and *file* elements are not expected to change in the future.

```
struct Control_Points
{
        int  count;     /*   number of control points    */
        double *e1;     /*   image east (column)         */
        double *n1;     /*   image north (row)           */
        double *e2;     /*   target east                 */
        double *n2;     /*   target north                */
        int *status;    /*   status of control point     */

} ;
```

The number of control points is *count*. Control point *i* is *e1*[i], *n1*[i], *e2*[i], *n2*[i], and its status is *status*[i].

Chapter 15

Raster Graphics Library

15.1. Introduction

The *Raster Graphics Library* provides the programmer with access to the GRASS graphics devices. **All video graphics calls are made through this library (directly or indirectly).** No standard/portable GRASS video graphics program drives any video display directly. This library provides a powerful, but limited number of graphics capabilities to the programmer. The tremendous benefit of this approach is seen in the ease with which GRASS graphics applications programs port to new machines or devices. Because no device-dependent code exists in application programs, virtually all GRASS graphics programs port without modification. Each graphics device must be provided a driver (or translator program). At run-time, GRASS graphics programs rendezvous with a user-selected driver program. Two significant prices are paid in this approach to graphics: 1) graphics displays run significantly slower, and 2) the programmer does not have access to fancy (and sometimes more efficient) resident library routines that have been specially created for the device.

This library uses a couple of simple concepts. First, there is the idea of a current screen location. There is nothing which appears on the graphics monitor to indicate the current location, but many graphic commands begin their graphics at this location. It can, of course, be set explicitly. Second, there is always a current color. Many graphic commands will do their work in the currently chosen color.

The programmer always works in the screen coordinate system. Unlike many graphics libraries developed to support CAD, there is no concept of a world coordinate system. The programmer must address graphics requests to explicit screen locations. This is necessary, especially in the interest of fast raster graphics.

The upper left hand corner of the screen is the origin. The actual pixel rows and columns which define the edge of the video surface are returned with calls to *R_screen_left(p. 150)*, *R_screen_rite(p. 150)*, *R_screen_bot(p. 150)*, and *R_screen_top(p. 150)*.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **R_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in *§24.5 Appendix G. Index to Raster Graphics Library* [*p.249*].

15.2. Connecting to the Driver

Before any other graphics calls can be made, a successful connection to a running and selected graphics driver must be made.

R_open_driver ( ) *initialize graphics*

Initializes connection to current graphics driver. Refer to GRASS User's Manual entries on the *monitor* command. If connection cannot be made, the application program sends a message to the user stating that a driver has not been selected or could not be opened. Note that only one application program can be connected to a graphics driver at once.

After all graphics have been completed, the driver should be closed.

R_close_driver ( ) *terminate graphics*

This routine breaks the connection with the graphics driver opened by R_open_driver( ).

15.3. Colors

GRASS is highly dependent on color for distinguishing between different categories. No graphic patterning is supported in any automatic way. There are two color modes. Fixed color refers to set and immutable color look-up tables on the hardware device. In some cases this is necessary because the graphics device does not contain programmer definable color look-up tables (LUT). Floating colors use the LUTs of the graphics device often in an interactive mode with the user. The basic impact on the user is that under the fixed mode, multiple maps can be displayed on the device with apparently no color interference between maps. Under float mode, the user may interactively manipulate the hardware color tables (using programs such as *d.colors*). Other than the fact that in float mode no more colors may be used than color registers available on the user's chosen driver, there are no other programming repercussions.

R_color_table_fixed ( ) *select fixed color table*

Select a fixed color table to be used for subsequent color calls. It is expected that the user will follow this call with a call to erase and reinitialize the [illegible]ire graphics screen.

Returns 0 if successful, non-zero if unsuccessful.

R_color_table_float ( ) *select floating color table*

Select a float color table to be used for subsequent color calls. It is expected that the user will follow this call with a call to erase and reinitialize the entire graphics screen.

Returns 0 if successful, non-zero if unsuccessful.

Colors are set using integer values in the range of 0-255 to set the **red, green,** and **blue** intensities. In float mode, these values are used to directly modify the hardware color look-up tables and instantaneously modify the appearance of colors on the monitor. In fixed mode, these values modify secondary look-up tables in the devices driver program so that the colors involved point to the closest available color on the device.

R_reset_color (red, green, blu, num) *define single color*

```
unsigned char red, green, blue ;
int num ;
```

Set color number **num** to the intensities represented by **red, green,** and **blue.**

R_reset_colors (min,max,red,green,blue) *define multiple colors*

```
int min, max ;
unsigned char *red, *green, *blue ;
```

Set color numbers **min** through **max** to the intensities represented in the arrays **red, green,** and **blue.**

R_color (color) *select color*

```
int color ;
```

Selects the **color** to be used in subsequent draw commands.

R_standard_color (color) *select standard color*

int color ;

Selects the standard **color** to be used in subsequent draw commands. The **color** value is best retrieved using *D_translate_color*(*p. 167*). See §*16 Display Graphics Library* [*p. 159*].

R_RGB_color (red,green,blue) *select color*

int red, green, blue ;

When in float mode (see *R_color_table_float*(*p. 149*)), this call selects the color most closely matched to the **red, green,** and **blue** intensities requested. These values must be in the range of 0-255.

15.4. Basic Graphics

Several calls are common to nearly all graphics systems. Routines exist to determine screen dimensions, as well as routines for moving, drawing, and erasing.

R_screen_bot ( ) *bottom of screen*

Returns the pixel row number of the bottom of the screen.

R_screen_top ( ) *top of screen*

Returns the pixel row number of the top of the screen.

R_screen_left ( ) *screen left edge*

Returns the pixel column number of the left edge of the screen.

R_screen_rite ( ) *screen right edge*

Returns the pixel column number of the right edge of the screen.

R_move_abs (x,y) *move current location*

int x, y;

Move the current location to the absolute screen coordinate **x,y.** Nothing is drawn on the screen.

R_move_rel (dx,dy) *move current location*

int dx, dy;

Shift the current screen location by the values in **dx** and **dy**:

```
Newx = Oldx + dx;
Newy = Oldy + dy;
```

Nothing is drawn on the screen.

R_cont_abs (x,y) *draw line*

int x, y;

Draw a line using the current color, selected via *R_color(p. 149)*, from the current location to the location specified by **x,y.** The current location is updated to **x,y.**

R_cont_rel (dx,dy) *draw line*

int dx, dy;

Draw a line using the current color, selected via *R_color(p. 149)*, from the current location to the relative location specified by **dx** and **dy.** The current location is updated:

```
Newx = Oldx + dx;
Newy = Oldy + dy;
```

R_box_abs (x1,y1,x2,y2) *fill a box*

int x1,y1;
int x2,y2;

A box is drawn in the current color using the coordinates **x1,y1** and **x2,y2** as opposite corners of the box. The current location is updated to **x2,y2.**

R_box_rel (dx,dy) *fill a box*

int dx, dy;

A box is drawn in the current color using the current location as one corner and the current location plus **dx** and **dy** as the opposite corner of the box. The current location is updated:

```
Newx = Oldx + dx;
Newy = Oldy + dy;
```

R_erase () *erase screen*

Erases the entire screen to black.

R_flush () *flush graphics*

Send all pending graphics commands to the graphics driver. This is done automatically when graphics input requests are made.

15.5. Poly Calls

In many cases strings of points are used to describe a complex line, a series of dots, or a solid polygon. Absolute and relative calls are provided for each of these operations.

R_polydots_abs (x,y,num) *draw a series of dots*

```
int *x, *y;
int num;
```

Pixels at the **num** absolute positions in the **x** and **y** arrays are turned to the current color. The current position is left updated to the position of the last dot.

R_polydots_rel (x,y,num) *draw a series of dots*

```
int *x, *y;
int num;
```

Pixels at the **num** relative positions in the **x** and **y** arrays are turned to the current color. The first position is relative to the starting current location; the succeeding positions are then relative to the previous position. The current position is updated to the position of the last dot.

R_polygon_abs (x,y,num) *draw a closed polygon*

```
int *x, *y;
int num;
```

The **num** absolute positions in the **x** and **y** arrays outline a closed polygon which is filled with the current color. The current position is left updated to the position of the last point.

R_polygon_rel (x,y,num) *draw a closed polygon*

```
int *x, *y;
int num;
```

The **num** relative positions in the **x** and **y** arrays outline a closed polygon which is filled with the current color. The first position is relative to the starting current location; the succeeding positions are then relative to the previous position. The current position is updated to the position of the last point.

R_polyline_abs (x,y,num) *draw an open polygon*

```
int *x, *y;
int num;
```

The **num** absolute positions in the **x** and **y** arrays are used to generate a multi-segment line (often curved). This line is drawn with the current color. The current position is left updated to the position of the last point.

Note. It is not assumed that the line is closed, i.e., no line is drawn from the last point to the first point.

R_polyline_rel (x,y,num) *draw an open polygon*

```
int *x, *y;
int num;
```

The **num** relative positions in the **x** and **y** arrays are used to generate a multi-segment line (often curved). The first position is relative to the starting current location; the succeeding positions are then relative to the previous position. The current position is updated to the position of the last point. This line is drawn with the current color.

Note. No line is drawn between the last point and the first point.

15.6. Raster Calls

GRASS, being principally a raster-based data system, requires efficient drawing of raster information to the display device. These calls provide that capability.

R_raster (num,nrows,withzero,raster) *draw a raster*

```
    int num, nrows, withzero ;
    int *raster ;
```

Starting at the current position, the **num** colors represented in the **raster** array are drawn for **nrows** consecutive pixel rows. The **withzero** flag is used to indicate whether 0 values are to be treated as a color (1) or should be ignored (0). If ignored, those screen pixels in these locations are not modified. This option is useful for graphic overlays.

R_set_RGB_color (red,green,blue) *initialize graphics*

```
    unsigned char red[256], green[256], blue[256] ;
```

The three 256 member arrays, **red, green,** and **blue,** establish look-up tables which translate the raw image values supplied in *R_RGB_raster(p. 154)* to color intensity values which are then displayed on the video screen. These two commands are tailor-made for imagery data coming off sensors which give values in the range of 0-255.

R_RGB_raster (num,nrows,red,green,blue,withzero) *draw a raster*

```
    int num, nrows, withzero ;
    unsigned char *red, *green, *blue ;
```

This is useful only in fixed color mode (see *R_color_table_fixed(p. 149)*). Starting at the current position, the **num** colors represented by the intensities described in the **red, green,** and **blue** arrays are drawn for **nrows** consecutive pixel rows. The raw values in these arrays are in the range of 0-255. They are used to map into the intensity maps which were previously sent with *R_set_RGB_color(p. 154)*. The **withzero** flag is used to indicate whether 0 values are to be treated as a color (1) or should be ignored (0). If ignored, those screen pixels in these locations are not modified. This option is useful for graphic overlays.

15.7. Text

These calls provide access to built-in vector fonts which may be sized and clipped to the programmers specifications.

R_set_window (top,bottom,left,right) *set text clipping window*

int top, bottom, left, right ;

Subsequent calls to *R_text(p. 156)* will have text strings clipped to the screen window defined by **top, bottom, left, right.**

R_font (font) *choose font*

char *font ;

Set current font to **font.** Available fonts are:

Font Name	Description
cyrilc	cyrillic
gothgbt	Gothic Great Britain triplex
gothgrt	Gothic German triplex
gothitt	Gothic Italian triplex
greekc	Greek complex
greekcs	Greek complex script
greekp	Greek plain
greeks	Greek simplex
italicc	Italian complex
italiccs	Italian complex small
italict	Italian triplex
romanc	Roman complex
romancs	Roman complex small
romand	Roman duplex
romanp	Roman plain
romans	Roman simplex
romant	Roman triplex
scriptc	Script complex
scripts	Script simplex

R_text_size (width, height) *set text size*

int width, height ;

Sets text pixel width and height to **width** and **height.**

R_text (text) *write text*

    char *text ;

Writes **text** in the current color and font, at the current text width and height, starting at the current screen location.

R_get_text_box (text, top, bottom, left, right) *get text extents*

    char *text ;
    int *top, *bottom, *left, *right ;

The extent of the area enclosing the **text** is returned in the integer pointers **top, bottom, left,** and **right.** No text is actually drawn. This is useful for capturing the text extent so that the text location can be prepared with proper background or border.

15.8. User Input

The raster library provides mouse (or other pointing device) input from the user. This can be accomplished with a pointer, a rubber-band line or a rubber-band box. Upon pressing one of three mouse buttons, the current mouse location and the button pressed are returned.

R_get_location_with_pointer (nx,ny,button) *get mouse location using pointer*

    int *nx, *ny, *button ;

A cursor is put on the screen at the location specified by the coordinate found at the **nx,ny** pointers. This cursor tracks the mouse (or other pointing device) until one of three mouse buttons are pressed. Upon pressing, the cursor is removed from the screen, the current mouse coordinates are returned by the **nx** and **ny** pointers, and the mouse button (1 for left, 2 for middle, and 3 for right) is returned in the **button** pointer.

R_get_location_with_line (x,y,nx,ny,button) *get mouse location using a line*

    int x, y;
    int *nx, *ny, *button ;

Similar to *R_get_location_with_pointer*(*p. 156*) except the pointer is replaced by a line which has one end fixed at the coordinate identified by the **x,y** values. The other end of the line is initialized at the coordinate identified by the **nx,ny** pointers. This end then tracks the mouse until a button is pressed. The mouse button (1 for left, 2 for middle, and 3 for right) is returned in the **button** pointer.

R_get_location_with_box (x,y,nx,ny,button) *get mouse location using a box*

```
int x, y;
int *nx, *ny, *button ;
```

Identical to *R_get_location_with_line*(*p. 156*) execept a rubber-band box is used instead of a rubber-band line.

15.9. Loading the Raster Graphics Library

The library is loaded by specifying $(RASTERLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(RASTERLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(RASTERLIB) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(RASTERLIB) $(GISLIB)

$(RASTERLIB):                      # in case the library changes
$(GISLIB):                         # in case the library changes
```

Note. This library must be loaded with $(GISLIB) since it uses routines from that library. See §*12 GIS Library* [*p. 63*] for details on that library.

This library is usually loaded with the $(DISPLAYLIB). See §*16 Display Graphics Library* [*p. 159*] for details on that library.

See §*11 Compiling GRASS Programs Using Gmake* [*p. 55*] for a complete discussion of Gmakefiles.

Chapter 16

Display Graphics Library

16.1. Introduction

This library provides a wide assortment of higher level graphics commands which in turn use the graphics raster library primitives. It is highly recommended that this section be used to understand how some of the GRASS 3.0 graphics commands operate. Such programs like *Dvect, Dgraph,* and *Dcell* demonstrate how these routines work together. The routines fall into four basic sets: 1) window creation and management, 2) coordinate conversion reoutines, 3) specialized efficient raster display routines, and 4) assorted miscellaneous routines like command line parsing and line clipping.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **D_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix F. Index to Display Graphics Library* [*p.247*].

16.2. Window Management

The following set of routines creates, destroys, and otherwise manages graphics windows.

D_new_window (name, top, bottom, left, right) *create new graphics window*

```
char *name ;
int top, bottom, left, right ;
```

Creates a new window **name** with coordinates **top, bottom, left,** and **right.** If **name** is the empty string "" (i.e., ***name** == 0), the routine returns a unique string in **name.**

D_set_cur_wind (name) *set current graphics window*

```
char *name ;
```

Selects the window **name** to be the current window. The previous current window (if there was one) is outlined in grey. The selected current window is outlined in white.

D_get_cur_wind (name) *identify current graphics window*

```
char *name ;
```

Captures the name of the current window in string **name.**

D_show_window (color) *outlines current window*

```
int color ;
```

Outlines current window in **color.** Appropriate colors are found in $GISBASE/src/D/libes/colors.h[1] and are spelled with lower-case letters.

D_get_screen_window (top, bottom, left, right) *retrieve current window coordinates*

```
int *top, *bottom, *left, *right ;
```

Returns current window's coordinates in the pointers **top, bottom, left,** and **right.**

D_check_map_window (window) *assign/retrieve current map window*

```
struct Cell_head *window ;
```

Graphics windows can have GRASS map windows associated with them. This routine passes the map **window** to the current graphics window. If a GRASS window is already associated with the graphics window, its information is copied into **window** for use by the calling program. Otherwise **window** is associated with the current graphics window.

[1] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p. 51*] for details.

D_reset_screen_window (top, bottom, left, right) *resets current window position*

    int top, bottom, left, right ;

Re-establishes the screen position of a window at the location specified by **top, bottom, left,** and **right.**

D_timestamp ( ) *give current time to window*

Timestamp the current window. This is used primarily to identify which windows are on top of which others.

D_erase_window ( ) *erase current window*

Erases the window on screen using the currently selected color.

D_remove_window ( ) *remove a window*

Remove any trace of current window.

D_clear_window ( ) *clears information about current window*

Removes all information about current window. This includes the map window and the window content lists.

16.3. Window Contents Management

This special set of graphics window management routines maintains lists of window contents.

D_add_to_list (string) *add command to window display list*

    char *string ;

Adds **string** to list of screen contents. By convention, **string** is a command string which could be used to recreate a part of the graphics contents. This should be done for all screen graphics except for the display of raster (grid cell) maps. The *D_set_cell_name()* routine is used for this special case.

D_set_cell_name (name) *add cell file name to display list*

```
char *name ;
```

Stores the cell file **name** in the information associated with the current window.

D_get_cell_name (name) *retrieve cell file name*

```
char *name ;
```

Returns the **name** of the cell file associated with the current window.

D_clear_window ( ) *clear window display lists*

Removes all display information lists associated with the current window.

16.4. Coordinate Transformation Routines

These routines provide coordinate transformation information. GRASS graphics programs typically work with the following three coordinate systems:

Coordinate system	Origin	
Display screen	upper left	(NW)
Earth window	lower left	(SW)
Array window	upper left	(NW)

Display screen coordinates are the physical coordinates of the display screen and are referred to as x and y. Earth window coordinates are from the GRASS database windows and are referred to as *east* and *north*. Array coordinates are the columns and rows relative to the GRASS window and are referred to as *column* and *row.*

The routine D_do_conversions( ) is called to establish the relationships between these different systems. Then a wide variety of accompanying calls provide access to conversion factors as well as conversion routines.

D_do_conversions (window, top, bottom, left, right) *initialize conversions*

```
struct Cell_head *window ;
int top, bottom, right, left ;
```

The relationship between the earth **window** and the **top, bottom, left,** and **right** screen coordinates is established, which then allows conversions between all three coordinate systems to be performed.

In the following routines, a value in one of the coordinate systems is converted to the equivalent value in a different coordinate system. The routines are named based on the coordinates systems involved. Display screen coordinates are represented by *d,* array coordinates by a, and earth coordinates by u (which stands for UTM).

double
D_u_to_a_row (north) *earth to array (north)*

    double north ;

Returns a *row* value in the array coordinate system when provided the corresponding **north** value in the earth coordinate system.

double
D_u_to_a_col (east) *earth to array (east)*

    double east ;

Returns a *column* value in the array coordinate system when provided the corresponding **east** value in the earth coordinate system.

double
D_a_to_d_row (row) *array to screen (row)*

    double row ;

Returns a y value in the screen coordinate system when provided the corresponding **row** value in the array coordinate system.

double
D_a_to_d_col (column) *array to screen (column)*

    double column ;

Returns an x value in the screen coordinate system when provided the corresponding **column** value in the array coordinate system.

double
D_u_to_d_row (north) *earth to screen (north)*

    double north ;

Returns a y value in the screen coordinate system when provided the corresponding **north** value in the earth coordinate system.

double
D_u_to_d_col (east) *earth to screen (east)*

double east ;

Returns an *x* value in the screen coordinate system when provided the corresponding **east** value in the earth coordinate system.

double
D_d_to_u_row (y) *screen to earth (y)*

double y ;

Returns a *north* value in the earth coordinate system when provided the corresponding **y** value in the screen coordinate system.

double
D_d_to_u_col (x) *screen to earth (x)*

double x ;

Returns an *east* value in the earth coordinate system when provided the corresponding **x** value in the screen coordinate system.

double
D_d_to_a_row (y) *screen to array (y)*

double y ;

Returns a *row* value in the array coordinate system when provided the corresponding **y** value in the screen coordinate system.

double
D_d_to_a_col (x) *screen to array (x)*

double x ;

Returns a *column* value in the array coordinate system when provided the corresponding **x** value in the screen coordinate system.

If the above routines prove too inefficient, the programmer can examine the source code for these routines to see how the conversions are done and create new conversion routines.

16.5. Raster Graphics

The display of raster graphics is very different from the display of vector graphics. While vector graphics routines can efficiently make use of world coordinates, the efficient rendering of raster images requires the programmer to work within the coordinate system of the graphics device. These routines make it easy to do just that. The application of these routines may be inspected in such commands as *combine* and *weight* which, under the user's option, display graphics results immediately to the screen.

D_cell_draw_setup (top, bottom, left, right) *prepare for raster graphics*

```
int top, bottom, left, right ;
```

The raster display subsystem establishes conversion parameters based on the screen extent defined by **top, bottom, left,** and **right,** all of which are obtainable from *D_get_screen_window(p. 160)* for the current window.

D_draw_cell_row (row, raster) *render a raster row*

```
int row ;
CELL *raster ;
```

The **row** gives the map array row. The **raster** array provides the categories for each map grid cell in that row. This routine is called consecutively with the information necessary to draw a raster image from north to south. No rows can be skipped. All screen pixel rows which represent the current map array row are rendered. The routine returns the map array row which is needed to draw the next screen pixel row.

D_overlay_cell_row (row, raster) *render a raster row without zeros*

```
int row ;
CELL *raster ;
```

Equivalent to D_draw_cell_row( ) except that locations with category 0 are left untouched, rather than being covered with the color for category 0.

16.6. Window Clipping

This section describes a routine which is quite useful in many settings. Window clipping is used for graphics display and digitizing.

D_clip (s, n, w, e, x, y, c_x, c_y) *clip coordinates to window*

```
double s, n, w, e;
double *x1, *y1, *x2, *y2 ;
```

A line represented by the coordinates **x1,y1** and **x2,y2** is clipped to the window defined by **s** (south), **n** (north), **w** (west), and **e** (east). Note that the following constraints must be true:

```
w < e
s < n
```

The **x1** and **x2** are values to be compared to **w** and **e**. The **y1** and **y2** are values to be compared to **s** and **n**.

The **x1** and **x2** values returned lie between **w** and **e**. The **y1** and **y2** values returned lie between **s** and **n**.

16.7. Pop-up Menus

D_popup (bcolor, tcolor, dcolor, top, left, size, options) *pop-up menu*

```
int bcolor ;
int tcolor ;
int dcolor ;
int left, top ;
int size ;
char *options[ ] ;
```

This routine provides a pop-up type menu on the graphics screen. For examples of how to use this routine see the source code for the GRASS 3.0 *display* program.[2] The **bcolor** specifies the background color. The **tcolor** is the text color. The **dcolor** specifies the color of the line used to divide the menu items. The **top** and **left** specify the placement of the top left corner of the menu on the screen. 0,0 is at the bottom left of the screen, and 100,100 is at the top right. The **size** of the text is given as a percentage of the vertical size of the screen. The **options** array is a NULL terminated array of character strings. The first is a menu title and the rest are the menu options (i.e., options[0] is the menu title, and options[1], options[2], etc., are the menu options). The last option must be the NULL pointer.

The coordinates of the bottom right of the menu are calculated based on the **top left** coordinates, the **size**, the number of **options**, and the longest option text length. If necessary, the menu coordinates are adjusted to make sure the menu is

[2] The source code for *display* is under $GISBASE/src/D/prog_inter/display.

on the screen.

D_popup( ) does the following:

1 Current screen contents under the menu are saved.
2 Area is blanked with the background color and fringed with the text color.
3 Menu options are drawn using the current font.
4 User uses the mouse to choose the desired option.
5 Menu is erased and screen is restored with the original contents.
6 Number of the selected option is returned to the calling program.

16.8. Colors

D_reset_colors (colors) *set colors in driver*

struct Colors *colors;

Turns color information provided in the **colors** structure into color requests to the graphics driver. These colors are for raster graphics, not lines or text. See §*12.9.3 Cell Color Table* [*p. 94*] for GIS Library routiones which use this structure.

D_translate_color (name) *color name to number*

char *name ;

Takes a color **name** in ascii and returns the color number for that color. Returns 0 if color is not known. The color number returned is for lines and text, not raster graphics.

16.9. Loading the Display Graphics Library

The library is loaded by specifying $(DISPLAYLIB), $(RASTERLIB) and $(GISLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(DISPLAYLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(DISPLAYLIB) $(RASTERLIB) $(GISLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(DISPLAYLIB) \
        $(RASTERLIB) $(GISLIB)

$(DISPLAYLIB):              # in case the library changes
$(RASTERLIB):               # in case the library changes
$(GISLIB):                  # in case the library changes
```

Note. This library uses routines in $(RASTERLIB). See §*15 Raster Graphics Library* [*p. 147*] for details on that library. Also $(RASTERLIB) uses routines in $(GISLIB). See §*12 GIS Library* [*p. 63*] for details on that library.

See §*11 Compiling GRASS Programs Using Gmake* [*p. 55*] for a complete discussion of Gmakefiles.

Chapter 17

Lock Library

17.1. Introduction

This library provides an advisory locking mechanism. It is based on the idea that a process will write a process id into a file to create the lock, and subsequent processes will obey the lock if the file still exists and the process whose id is written in the file is still running.

17.2. Lock Routine Synopses

lock_file (file, pid) *create a lock*

```
char *file;
int pid;
```

This routine decides if the lock can be set and, if so, sets the lock. If **file** does not exist, the lock is set by creating the file and writing the **pid** (process id) into the **file**. If **file** exists, the lock may still be active, or it may have been abandoned. To determine this, an integer is read out of the file. This integer is taken to be the process id for the process which created the lock. If this process is still running, the lock is still active and the lock request is denied. Otherwise the lock is considered to have been abandoned, and the lock is set by writing the **pid** into the **file**.

Return codes:

1	ok, lock request was successful
0	sorry, another process already has the file locked
-1	error. could not create the file
-2	error. could not read the file
-3	error. could not write the file

unlock_file (file) *remove a lock*

```
    char *file;
```

This routine releases the lock by unlinking **file**. This routine does NOT check to see that the process unlocking the file is the one which created the lock. The file is simply unlinked. Programs should of course unlock the lock if they created it. (Note, however, that the mechanism correctly handles abandoned locks.)

Return codes:

1	ok. lock file was removed
0	ok. lock file was never there
-1	error. lock file remained after attempt to remove it.

17.3. Use and Limitations

It is worth noting that the process id used to lock the file does not have to be the process id of the process which actually creates the lock. It could be the process id of a parent process. The GRASS start-up shells, for example, invoke an auxiliary "locking" program that is told the file name and the process id to use. The start-up shells simply use a hidden file in the user's home directory as the lock file,[1] and their own process id as the locking pid, but let the auxiliary program actually do the locking (since the lock must be done by a program, not a shell script). The only consideration is that the parent process not exit and abandon the lock.

Warning. Locking based on process ids requires that all processes which access the lock file run on the same cpu. It will not work under a network environment since a process id alone (without some kind of host identifier) is not sufficient to identify a process.

17.4. Loading the Lock Library

The library is loaded by specifying $(LOCKLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

[1] This file is .gislock under GRASS 3.0.

Gmakefile for $(LOCKLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(LOCKLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(LOCKLIB)

$(LOCKLIB): # in case the library changes
```

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

Chapter 18

Rowio Library

18.1. Introduction

Sometimes it is necessary to process large files which contain data in a matrix format and keep more than one row of the data in memory at a time. For example, suppose a program were required to look at five rows of data of input to produce one row of output (neighborhood function). It would be necessary to allocate five memory buffers, read five rows of data into them, and process the data in the five buffers. Then the next row of data would be read into the first buffer, overwriting the first row, and the five buffers would again be processed, etc. This memory management complicates the programming somewhat and is peripheral to the function being developed.

The *Rowio Library* routines handle this memory management. These routines need to know the number of rows of data that are to be held in memory and how many bytes are in each row. They must be given a file descriptor open for reading. In order to abstract the file i/o from the memory management, the programmer also supplies a subroutine which will be called to do the actual reading of the file. The library routines efficiently see to it that the rows requested by the program are in memory.

Also, if the row buffers are to be written back to the file, there is a mechanism for handling this management as well.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **rowio_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix H. Index to Rowio Library* [*p. 251*].

18.2. Rowio Routine Synopses

The routines in the *Rowio Library* are described below. They use a data structure called ROWIO which is defined in the header file "rowio.h" that must be included in any code using these routines:[1]

```
#include "rowio.h"
```

rowio_setup (r, fd, nrows, len, getrow, putrow) *configure rowio structure*

```
ROWIO *r;
int fd, nrows, len;
int (*getrow)( );
int (*putrow)( );
```

Rowio_setup( ) initializes the ROWIO structure **r** and allocates the required memory buffers. The file descriptor **fd** must be open for reading. The number of rows to be held in memory is **nrows**. The length in bytes of each row is **len**. The routine which will be called to read data from the file is **getrow**( ) and must be provided by the programmer. If the application requires that the rows be written back into the file if changed, the file descriptor **fd** must be open for write as well, and the programmer must provide a **putrow**( ) routine to write the data into the file. If no writing of the file is to occur, specify NULL for **putrow**( ).

Return codes:

1	ok
-1	there is not enough memory for buffer allocation

The **getrow**( ) routine will be called as follows:

```
getrow (fd, buf, n, len)
        int fd;
        char *buf;
        int n, len;
```

When called, **getrow**( ) should read data for row **n** from file descriptor **fd** into **buf** for **len** bytes. It should return 1 if the data is read ok, 0 if not.

The **putrow**( ) routine will be called as follows:

[1] The GRASS compilation process, described in §*11 Compiling GRASS Programs Using Gmake* [p. 55], automatically tells the C compiler how to find this and other GRASS header files.

```
putrow (fd, buf, n, len)

        int fd;
        char *buf;
        int n, len;
```

When called, **putrow()** should write data for row **n** to file descriptor **fd** from **buf** for **len** bytes. It should return 1 if the data is written ok, 0 if not.

char *
rowio_get (r, n)   *read a row*

```
    ROWIO *r;
    int n;
```

Rowio_get() returns a buffer which holds the data for row **n** from the file associated with ROWIO structure **r.** If the row requested is not in memory, the **getrow()** routine specified in *rowio_setup(p. 174)* is called to read row **n** into memory and a pointer to the memory buffer containing the row is returned. If the data currently in the buffer had been changed by *rowio_put(p. 176)*, the **putrow()** routine specified in *rowio_setup(p. 174)* is called first to write the changed row to disk. If row **n** is already in memory, no disk read is done. The pointer to the data is simply returned.

Return codes:

NULL	**n** is negative, or **getrow()** returned 0 (indicating an error condition).
!NULL	pointer to buffer containing row **n**.

rowio_forget (r, n)   *forget a row*

```
    ROWIO *r;
    int n;
```

Rowio_forget() tells the routines that the next request for row **n** must be satisifed by reading the file, even if the row is in memory.

For example, this routine should be called if the buffer returned by *rowio_get(p. 175)* is later modified directly without also writing it to the file. See *§18.3 Rowio Programming Considerations* [p. 176].

rowio_fileno (r) *get file descriptor*

ROWIO *r;

Rowio_fileno( ) returns the file descriptor associated with the ROWIO structure.

rowio_release (r) *free allocated memory*

ROWIO *r;

Rowio_release( ) frees all the memory allocated for ROWIO structure **r.** It does not close the file descriptor associated with the structure.

rowio_put (r, buf, n) *write a row*

```
ROWIO *r;
char *buf;
int n;
```

Rowio_put( ) writes the buffer **buf,** which holds the data for row **n,** into the ROWIO structure **r.** If the row requested is currently in memory, the buffer is simply copied into the structure and marked as having been changed. It will be written out later. Otherwise it is written immediately. Note that when the row is finally written to disk, the **putrow**( ) routine specified in *rowio_setup(p. 174)* is called to write row **n** to the file.

rowio_flush (r) *force pending updates to disk*

ROWIO *r;

Rowio_flush( ) forces all rows modified by *rowio_put(p. 176)* to be written to the file. This routine must be called before closing the file or releasing the rowio structure if rowio_put( ) has been called.

18.3. Rowio Programming Considerations

If the contents of the row buffer returned by rowio_get( ) are modified, the programmer must either write the modified buffer back into the file or call rowio_forget( ). If this is not done, the data for the row will not be correct if requested again. The reason is that if the row is still in memory when it is requested a second time, the new data will be returned. If it isn't in memory, the file will be read to get the row and the old data will be returned. If the modified row data is written back into the file, these routines will behave correctly and can be used to edit files. If it is not written back into the file, rowio_forget( ) must be called to force the row to be read from the file when it is next requested.

Rowio_get( ) returns NULL if getrow( ) returns 0 (indicating an error reading the file), or if the row requested is less than 0. The calling sequence for rowio_get( ) does not permit error codes to be returned. If error codes are needed, they can be recorded by getrow( ) in global variables for the rest of the program to check.

18.4. Loading the Rowio Library

The library is loaded by specifying $(ROWIOLIB)[2] in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(ROWIOLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(ROWIOLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(ROWIOLIB)

$(ROWIOLIB): # in case the library changes
```

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

[2] This variable was NOT defined in releases 3.0 and 3.0A. Edit the file *$GISBASE/src/CMD/make.mid* and add the line **ROWIOLIB=$(LIBDIR)/rowio.a** at the bottom of the file.

Chapter 19

Segment Library

19.1. Introduction

Large data files which contain data in a matrix format often need to be accessed in a non-sequential or random manner. This requirement complicates the programming. Methods for accessing the data are to:

(1) read the entire data file into memory and process the data as a two-dimensional matrix,

(2) perform direct access i/o to the data file for every data value to be accessed, or

(3) read only portions of the data file into memory as needed.

Method (1) greatly simplifies the programming effort since i/o is done once and data access is simple array referencing. However, it has the disadvantage that large amounts of memory may be required to hold the data. The memory may not be available, or if it is, system paging of the program may severely degrade performance. Method (2) is not much more complicated to code and requires no significant amount of memory to hold the data. But the i/o involved will certainly degrade performance. Method (3) is a mixture of (1) and (2). Memory requirements are fixed and data is read from the data file only when not already in memory. However the programming is more complex.

The routines provided in this library are an implementation of method (3). They are based on the idea that if the original matrix were segmented or partitioned into smaller matrices these segments could be managed to reduce both the memory required and the i/o. Data access along connected paths through the matrix, (i.e., moving up or down one row and left or right one column) should benefit.

In most applications, the original data is not in the segmented format. The data must be transformed from the non-segmented format to the segmented format. This means reading the original data matrix row by row and writing each row to a new file with the segmentation organization. This step corresponds to the i/o step of method (1).

Then data can be retrieved from the segment file through routines by specifying the row and column of the original matrix. Behind the scenes, the data is paged into memory as needed and the requested data is returned to the caller.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **segment_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix I. Index to Segment Library* [p. 253].

19.2. Segment Routines

The routines in the *Segment Library* are described below, more or less in the order they would logically be used in a program. They use a data structure called SEGMENT which is defined in the header file "segment.h" that must be included in any code using these routines:[1]

```
        #include "segment.h"
```

The first step is to create a file which is properly formatted for use by the *Segment Library* routines:

segment_format (fd, nrows, ncols, srows, scols, len) *format a segment file*

```
        int fd, nrows, ncols, srows, scols, len;
```

The segmentation routines require a disk file to be used for paging segments in and out of memory. This routine formats the file open for write on file descriptor **fd** for use as a segment file. A segment file must be formatted before it can be processed by other segment routines. The configuration parameters **nrows, ncols, srows, scols,** and **len** are written to the beginning of the segment file which is then filled with zeros.

The corresponding non-segmented data matrix, which is to be transferred to the segment file, is **nrows** by **ncols**. The segment file is to be formed of segments which are **srows** by **scols**. The data items have length **len** bytes. For example, if the data type is *int*, **len** is *sizeof(int)*.

Return codes are: 1 if ok; else -1 could not seek or write *fd*, or -3 illegal configuration parameter(s).

The next step is to initialize a SEGMENT structure to be associated with a segment file formatted by *segment_format*(p. 180).

[1] The GRASS compilation process, described in §*11 Compiling GRASS Programs Using Gmake* [p. 55], automatically tells the C compiler how to find this and other GRASS header files.

segment_init (seg, fd, nsegs) *initialize segment structure*

```
SEGMENT *seg;
int fd, nsegs;
```

Initializes the **seg** structure. The file on **fd** is a segment file created by *segment_format*(*p. 180*) and must be open for reading and writing. The segment file configuration parameters *nrows, ncols, srows, scols,* and *len,* as written to the file by *segment_format*(*p. 180*), are read from the file and stored in the **seg** structure. **Nsegs** specifies the number of segments that will be retained in memory. The minimum value allowed is 1.

Note. The size of a segment is *scols*srows*len* plus a few bytes for managing each segment.

Return codes are: 1 if ok; else -1 could not seek or read segment file, or -2 out of memory.

Then data can be written from another file to the segment file row by row:

segment_put_row (seg, buf, row) *write row to segment file*

```
SEGMENT *seg;
char *buf;
int row;
```

Transfers non-segmented matrix data, row by row, into a segment file. **Seg** is the segment structure that was configured from a call to *segment_init*(*p. 181*). **Buf** should contain *ncols*len* bytes of data to be transferred to the segment file. **Row** specifies the row from the data matrix being transferred.

Return codes are: 1 if ok; else -1 could not seek or write segment file.

Then data can be read or written to the segment file randomly:

segment_get (seg, value, row, col) *get value from segment file*

```
SEGMENT *seg;
char *value;
int row, col;
```

Provides random read access to the segmented data. It gets *len* bytes of data into **value** from the segment file **seg** for the corresponding **row** and **col** in the original data matrix.

Return codes are: 1 if ok; else -1 could not seek or read segment file.

segment_put (seg, value, row, col) *put value to segment file*

```
SEGMENT *seg;
char *value;
int row, col;
```

Provides random write access to the segmented data. It copies *len* bytes of data from **value** into the segment structure **seg** for the corresponding **row** and **col** in the original data matrix.

The data is not written to disk immediately. It is stored in a memory segment until the segment routines decide to page the segment to disk.

Return codes are: 1 if ok; else -1 could not seek or write segment file.

After random reading and writing is finished, the pending updates must be flushed to disk:

segment_flush (seg) *flush pending updates to disk*

```
SEGMENT *seg;
```

Forces all pending updates generated by *segment_put*(*p. 182*) to be written to the segment file **seg**. Must be called after the final segment_put( ) to force all pending updates to disk. Must also be called before the first call to *segment_get_row*(*p. 182*).

Now the data in segment file can be read row by row and transferred to a normal sequential data file:

segment_get_row (seg, buf, row) *read row from segment file*

```
SEGMENT *seg;
char *buf;
int row;
```

Transfers data from a segment file, row by row, into memory (which can then be written to a regular matrix file). **Seg** is the segment structure that was configured from a call to *segment_init*(*p. 181*). **Buf** will be filled with *ncols*len* bytes of data corresponding to the **row** in the data matrix.

Return codes are: 1 if ok; else -1 could not seek or read segment file.

Finally, memory allocated in the SEGMENT structure is freed:

segment_release (seg) *free allocated memory*

    SEGMENT *seg;

Releases the allocated memory associated with the segment file **seg**. Does not close the file. Does not flush the data which may be pending from previous *segment_put(p. 182)* calls.

19.3. How to Use the Library Routines

The following should provide the programmer with a good idea of how to use the *Segment Library* routines. The examples assume that the data is integer. The first step is the creation and formatting of a segment file. A file is created, formatted and then closed:

```
fd = creat (file,0666);
segment_format (fd, nrows, ncols, srows, scols, sizeof(int));
close(fd)
```

The next step is the conversion of the non-segmented matrix data into segment file format. The segment file is reopened for read and write, initialized, and then data read row by row from the original data file and put into the segment file:

```
int buf[NCOLS];
SEGMENT seg;

fd = open (file, 2);
segment_init (&seg, fd, nseg)

for (row = 0; row < nrows; row++)
{
        <code to get original matrix data for row into buf>

        segment_put_row (&seg, buf, row);

}
```

Of course if the intention is only to add new values rather than update existing values, the step which transfers data from the original matrix to the segment file, using segment_put_row( ), could be omitted, since *segment_format(p. 180)* will fill the segment file with zeros.

The data can now be accessed directly using *segment_get(p. 181)*. For example, to get the value at a given row and column:

```
int value;
SEGMENT seg;

segment_get (&seg, &value, row, col);
```

Similarly *segment_put*(*p. 182*) can be used to change data values in the segment file:

```
int value;
SEGMENT seg;

value = 10;
segment_put (&seg, &value, row, col);
```

Warning. It is an easy mistake to pass a value directly to segment_put( ). The following should be avoided:

```
segment_put (&seg, 10, row, col);   /* this won't work */
```

Once the random access processing is complete, the data would be extracted from the segment file and written to a non-segmented matrix data file as follows:

```
segment_flush (&seg);

for (row = 0; row < nrows; row++)
{
        segment_get_row (&seg, buf, row);

        <code to put buf into a matrix data file for row>

}
```

Finally, the memory allocated for use by the segment routines would be released and the file closed:

```
segment_release (&seg);
close (fd);
```

Note. The *Segment Library* does not know the name of the segment file. It does not attempt to remove the file. If the file is only temporary, the programmer should remove the file after closing it.

19.4. Loading the Segment Library

The library is loaded by specifying $(SEGMENTLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(SEGMENTLIB)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(SEGMENTLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(SEGMENTLIB)

$(SEGMENTLIB): # in case the library changes
```

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

Chapter 20

Vask Library

20.1. Introduction

The *Vask Library* (visual-ask) provides an easy means to communicate with a user one page at a time. That is, a page of text can be provided to the user with information and question prompts. The user is allowed to move the cursor[1] from prompt to prompt answering questions in any desired order. Users' answers are confined to the programmer-specified screen locations.

This interface is used in many interactive GRASS programs.[2] For the user, the *Vask Library* provides a very consistent and simple interface. It is also fairly simple and easy for the programmer to use.

Note. All routines and global variables in this library, documented or undocumented, start with the prefix **V_**. To avoid name conflicts, programmers should not create variables or routines in their own programs which use this prefix.

An alphabetic index is provided in §*24.5 Appendix J. Index to Vask Library* [*p.255*].

20.2. Vask Routine Synopses

The routines in the *Vask Library* are described below, more or less in the order they would logically be used in a program. The *Vask Library* maintains a private data space for recording the screen description. With the exception of V_call( ), which does all the screen painting and user interaction, *vask* routines only modify the screen description and do not update the screen itself.

[1] The functions in this library make use of the curses library and termcap descriptions. As when using vi, the user must have the TERM variable set.

[2] The GRASS *window* command is a good example, as are *reclass* and *mask*.

V_clear ( )   *initialize screen description*

This routine initializes the screen description information, and must be called before each new screen layout description.

V_line (num, text)   *add line of text to screen*

```
int num;
char *text;
```

This routine is used to place lines of text on the screen. **Row** is an integer value of 0-22 specifying the row on the screen where the **text** is placed. The top row on the screen is row 0.

Warning. V_line( ) does not copy the text to the screen description. It only saves the text address. This implies that each call to V_line( ) must use a different text buffer.

V_const (value, type, row, col, len)   *define screen constant*

V_ques (value, type, row, col, len)   *define screen question*

Ctype *value;   (*Ctype* is one of int, long, float, double, or char)
char type;
int row, col, len;

These two calls use the same syntax. V_const( ) and V_ques( ) specify that the contents of memory at the address of **value** are to be displayed on the screen at location **row, col** for **len** characters. V_ques( ) further specifies that this screen location is a prompt field. The user will be allowed to change the field on the screen and thus change the **value** itself. V_const( ) does not define a prompt field, and thus the user will not be able to change these values.

Value is a pointer to an int, long, float, double, or char string. **Type** specifies what type value points to: 'i' (int), 'l' (long), 'f' (float), 'd' (double), or 's' (character string). **Row** is an integer value of 0-22 specifying the row on the screen where the value is placed. The top row on the screen is row 0. **Col** is an integer value of 0-79 specifying the column on the screen where the value is placed. The leftmost column on the screen is column 0. **Len** specifies the number of columns that the value will use.

Note that the size of a character array passed to V_ques( ) must be at least one byte longer than the length of the prompt field to allow for NULL termination.

Currently, you are limited to 20 constants and 80 variables.

Warning. These routines store the address of **value** and not the value itself. This implies that different variables must be used for different calls. Programmers will instinctively use different variables with V_ques( ), but it is a stumbling block for V_const( ). Also, the programmer must initialize **value** prior to calling these routines.[3]

V_float_accuracy (num) *set number of decimal places*

int num;

V_float_accuracy( ) defines the number of decimal places in which floats and doubles are displayed or accepted. **Num** is an integer value defining the number of decimal places to be used. This routine affects subsequent calls to V_const( ) and V_ques( ). Various inputs or displayed constants can be represented with different numbers of decimal places within the same screen display by making different calls to V_float_accuracy( ) before calls to V_ques( ) or V_const( ). V_clear( ) resets the number of decimal places to 2.

V_call ( ) *interact with the user*

V_call( ) clears the screen and writes the text and data values specified by V_line( ), V_ques( ) and V_const( ) to the screen. It interfaces with the user, collecting user responses in the V_ques( ) fields until the user is satisfied. A message is automatically supplied on line number 23, explaining to the user to enter an ESC when all inputs have been supplied as desired. V_call( ) ends when the user hits ESC and returns a value of 1 (but see V_intrpt_ok( ) below).

No error checking is done by V_call( ). Instead, all variables used in V_ques( ) calls must be checked upon return from V_call( ). If the user has supplied inappropriate information, the user can be informed, and the input prompted for again by further calls to V_call( ).

V_intrpt_ok ( ) *allow ctrl-c*

V_call( ) normally only allows the ESC character to end the interactive input session. Sometimes it is desirable to allow the user to cancel the session. To provide this alternate means of exit, the programmer can call V_intrpt_ok( ) before V_call( ). This allows the user to enter Ctrl-C, which causes V_call( ) to return a value of 0 instead of 1.

A message is automatically supplied to the user on line 23 saying to use Ctrl-C to cancel the input session. The normal message accompanying V_call( ) is moved up to line 22.

Note. When V_intrpt_ok( ) is called, the programmer must limit the use of V_line( ), V_ques( ), and V_const( ) to lines 0-21.

[3] Technically **value** needs to be initialized before the call to V_call( ) since V_const( ) and V_ques( ) only store the address of **value**. V_call( ) looks up the values and places them on the screen.

V_intrpt_msg (text)   *change ctrl-c message*

char *text;

A call to V_intrpt_msg( ) changes the default V_intrpt_ok( ) message from (OR <Ctrl-C> TO CANCEL) to (OR <Ctrl-C> TO *msg*). The message is (re)set to the default by V_clear( ).

20.3. An Example Program

Following is the code for a simple program which will prompt the user to enter an integer, a floating point number, and a character string.

```
#define LEN 15
main( )
{
   int i ;                                      /* the variables */
   float f ;
   char s[LEN] ;

   i = 0 ;                                      /* initialize the variables */
   f = 0.0 ;
   *s = 0 ;

   V_clear( ) ;                                 /* clear vask info */

   V_line( 5, "   Enter an Integer ") ;         /* the text */
   V_line( 7, "   Enter a Decimal   ") ;
   V_line( 9, "   Enter a character string ") ;

   V_ques ( &i, 'i', 5, 30,  5) ;               /* the prompt fields */
   V_ques ( &f, 'f', 7, 30,  5) ;
   V_ques ( s,  's', 9, 30, LEN - 1) ;

   V_intrpt_ok( );                              /* allow ctrl-c */

   if (!V_call( ))                              /* display and get user input */
      exit(1);                                  /* exit if ctrl-c */

  printf ("%d %f %s\n", i, f, s) ;              /* ESC, so print results */
  exit(0);
}
```

The user is presented with the following screen:

```
Enter an Integer               0____

Enter a Decimal                0.00_

Enter a character string       _________



AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
                (OR <Ctrl-C> TO CANCEL)
```

The user has several options.

<CR>	moves the cursor to the next prompt field.
CTRL-K	moves the cursor to the previous prompt field.
CTRL-H	moves the cursor backward non-destructively within the field.
CTRL-L	moves the cursor forward non-destructively within the field.
CTRL-A	writes a copy of the screen to a file named *visual_ask* in the user's home directory.
ESC	returns control to the calling program with a return value of 1.
CTRL-C	returns control to the calling program with a return value of 0.

Displayable ascii characters typed by the user are accepted and displayed. Control characters (other than those with special meaning listed above) are ignored.

20.4. Loading the Vask Library

Compilations must specify the vask, curses, and termcap libraries. The library is loaded by specifying $(VASK) and $(VASKLIB) in the Gmakefile. The following example is a complete Gmakefile which compiles code that uses this library:

Gmakefile for $(VASK)

```
OBJ = main.o sub1.o sub2.o

pgm: $(OBJ) $(VASKLIB)
    $(CC) $(LDFLAGS) -o $@ $(OBJ) $(VASK)

$(VASKLIB): # in case the library changes
```

Note. The target *pgm* depends on the object files $(OBJ) and the *Vask Library* $(VASKLIB). This is done so that modifications to any of the $(OBJ) files or to the $(VASKLIB) itself will force program reloading. However, the compile rule specifies $(OBJ) and $(VASK), rather than $(OBJ) and $(VASKLIB). This is because $(VASK) specifies both the UNIX curses and termcap libraries as well as $(VASKLIB).

See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for a complete discussion of Gmakefiles.

20.5. Programming Considerations

The order of movement from prompt field to prompt field is dependent on the ordering of calls to V_ques( ), not on the line numbers used within each call.

Information cannot be entered beyond the edges of the prompt fields. Thus, the user response is limited by the number of spaces in the prompt field provided in the call to V_ques( ). Some interpretation of input occurs during the interactive information gathering session. When the user enters <CR> to move to the next prompt field, the contents of the current field are read and rewritten according to the value type associated with the field. For example, non-numeric responses (e.g., "abc") in an integer field will get turned to a 0, and floating point numbers will be truncated (e.g., 54.87 will become 54).

No error checking (other than matching input with variable type for that input field) is done by V_call( ). This must be done, by the programmer, upon return from V_call( ).

Calls to V_line( ), V_ques( ), and V_const( ) store only pointers, not contents of memory. At the time of the call to V_call( ), the contents of memory at these addresses are copied into the appropriate places of the screen description. Care should be taken to use distinct pointers for different fields and lines of text. For example, the following mistake should be avoided:

```
char text[100];

V_clear( );

sprintf(text,"            Welcome to GRASS  ");
V_line(3,text);
sprintf(text,"   which is a product of the US Army CERL  ");
V_line(5,text);

V_call( );
```

since this results in the following (unintended) screen:

```


which is a product of the US Army CERL

which is a product of the US Army CERL






AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
                (OR <Ctrl-C> TO CANCEL)
```

Warning. Due to a problem in a routine within the curses library,[4] the Vask routines use the curses library in a somewhat unorthodox way. This avoided the problem within curses, but means that the programmer cannot mix the use of the *Vask Library* with direct calls to curses routines. **Any program using the *Vask Library* should not call curses library routines directly.**

[4] Specifically, memory allocated by initscr( ) was not freed by endwin( ).

Chapter 21

Writing a Digitizer Driver

21.1. Introduction

A digitizer device driver consists of a library of device-dependent functions that are linked into digitizer programs. This chapter describes those functions that are needed to create a digitizer device driver compatible with GRASS map development software.

Section §*21.2 Writing the Digitizer Device Driver* [*p. 195*] explains how digitizer drivers are written, while section §*21.3 Discussion of the Finer Points (Hints)* [*p. 203*] describes problems and pitfalls encountered during the development of the Altek driver.

21.2. Writing the Digitizer Device Driver

Source code for the digitizer drivers is kept in

$GISBASE/src/mapdev/digitizers[1]

Separate sub-directories contain the individual drivers. When a new driver is written, it should be placed here in a new sub-directory.

It is helpful to examine the source code for existing drivers located here, and to attend a demonstration of the GRASS digitizing program *digit*, before developing a new driver.

21.2.1. Functions to be Written

This section describes the device-dependent library functions that must be written. Each of these functions must be present in the library. Function descriptions are organized by file name. (The file names are those used by current GRASS digitizer drivers. File names are printed in bold, along the left-hand margin of the page.) These

[1] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p. 51*] for details.

files and functions can be copied from one of the existing digitizer driver libraries and altered to suit the needs of a particular driver.

Note. Although it is strongly recommended that the programmer use the file names listed below (for reasons set forth in §*21.2.3 Compiling the Device Driver* [*p.202*]), other files names may be used instead.

dig_menu.h

This file contains the menu that is displayed while digitizing. The menu should indicate the purpose of the buttons on the cursor for the particular digitizer. The menu is stored in **dig_menu**:

```
char *dig_menu[ ] ;
```

An example of how the Altek driver uses this function to create a menu is given below:

```
#define dig_menu_lines      16

char  *dig_menu[ ] = {
"   GRASS-DIGIT Version 3.0                          Digitizing menu    ",
"  ---------------------------------------------------------------------",
"   ALTEK digitizer                   | AMOUNT DIGITIZED                ",
"      Cursor keys:                   |   # Lines:                      ",
"       <0>  digitize point           |   # Area edges:                 ",
"       <1>  quit digitizing          |---------------------------------",
"       <2>  update monitor           |                                 ",
"       <3>  toggle point/stream mode |   Total points:                 ",
"  -----------------------------------|---------------------------------",
"                                     |  CURRENT DIGITIZER PARAMS.      ",
"                                     |                                 ",
"                                     |                                 ",
"                                     |  MODE          TYPE             ",
"                                     |   point        line             ",
"                                     |   stream       area edge        ",
"                                     |                                 "
} ;
```

Note. The menu must be exactly as it appears here, except that the text in **bold** may be replaced by the appropriate text for the digitizer.

dig_curses.c

This file only contains #includes. It is used to set up the digitizing menu in the "dig_menu.h" file. This file must look like this:

```
#include <curses.h>

#include "dig_menu.h"
#include "../../digit/digit.h"
#include "../../digit/menu.h"
#include "../../libes/head.h"

#include "../../digit/curses.c"
```

setup_driver.c

```
D_setup_driver (device)
    char  *device ;
```

This function opens the device (which is a *tty* port) and initializes the digitizer.

Note. This function should not set the origin. The origin is set later by the function *D_setup_origin*(*p. 199*).

dig_dev.c

```
D_get_scale(scale)
    float  *scale ;
```

This function sets **scale** to the digitizer resolution in units of lines per inch.[2] For example, on a digitizer having a resolution of 1000 lines per inch, **scale** would be set to .001.

coll_pts.c

```
#include   "digit.h"
#include   "globals.h"

collect_points (mode, type, np, x, y)
    int  mode,  type ;
    int  *np ;
    double  **x,  **y ;
```

This routine is called to collect points that represent a single vector (or arc) from the digitizer.

The points should be collected into static arrays or dynamically allocated arrays, transformed from digitizer coordinates to database coordinates using *transform_a_into_b*(*p. 201*), and plotted on the graphics monitor using *plot_points*(*p. 201*). Then **x** and **y** are set to point to these arrays, and **np** set to the number of points collected.

[2] Almost all digitizers describe their resolution in lines per inch (lpi). This is essentially equivalent to pixels per inch, or dots per inch.

The digitizing **mode** may be either STREAM or POINT: STREAM indicates that the digitizer should collect a continuous stream of points; POINT indicates that the digitizer should collect points under user control (i.e., each time the user presses a button, the foot-switch, or a key on the keyboard). The *collect_points* ( ) function can be written to allow interactive toggling between the two modes during a single call.

The **type** is set to AREA when the vector to be collected is an area edge, and to LINE when it is is a linear feature. The **type** is of no interest to *collect_points* ( ) itself, but is passed to the function *plot_points(p. 201)*, which draws lines on the graphics monitor.

This function should return 1 if digitizing in STREAM mode occurred (i.e., either because **mode** was initially STREAM, or because the user changed to STREAM mode), and 0 otherwise.[3]

Note. This routine is responsible for plotting the vector on the graphics monitor, but it should do it responsibly. This means that while digitizing in POINT mode, the line-segments should be plotted immediately; while digitizing in STREAM mode, the points should be plotted only when the digitizing is finished, or when the user toggles to POINT mode.

Note. If the cursor has buttons, they can be used to change the digitizing **mode** as well as end the digitizing. If the digitizer has a foot-switch instead of buttons, the foot-switch should be used to end the digitizing (toggling modes would not be supported in this case). If the digitizer has neither buttons nor a foot-switch, then the keyboard must be used, even in STREAM mode. (See GeoGraphics driver for code that polls the keyboard.)

interface.c

This file contains a number of functions. The following functions return information about digitizer capabilities:

D_cursor_buttons( )

If the digitizer cursor buttons are to be used by the digitizing programs, there must be at least five buttons. This function returns 1 if the cursor has five or more buttons; otherwise, it returns 0.

D_foot_switch( )

This function returns 1 if there is a usable foot-switch. It returns 0 if the digitizer has no foot-switch.

Note. If there are five or more buttons on the cursor, the value returned by

[3] STREAM mode indicates to *digit* that the resulting vector should be pruned.

D_foot_switch( ) is ignored (i.e., it is assumed that there is no foot-switch). See *D_cursor_buttons*(*p. 198*).

D_start_button( )

This function tells the driver how the cursor buttons are labeled (i.e., the labels that the user sees on the buttons). If the first button is labeled 1, then this routine returns 1. If the first button is labeled 0, then this routine returns 0.

It should return -1 if the digitizer cursor buttons are not being used by the driver. See *D_cursor_buttons*(*p. 198*).

For example, if the digitizer buttons are labeled 0-9, then this routine would return 0. If the digitizer buttons are labeled 1-16, then this routine would return 1.

The following routines perform digitizer configuration:

D_setup_origin( )

This routine sets the digitizer's origin (0,0). This routine should only return if successful, and should return a value of 0. If it fails, an error message should be sent to the terminal screen with *Write_info*(*p. 202*), and the program terminated with a call to *close_down*(*p. 201*).

Note. Frequently, the location of the digitizer's origin can be set to some default value, without any input from the user. Otherwise, this routine must ask the user to set the origin. The routine *Write_info*(*p. 202*) should be used to print instructions for the user. (Refer to the GeoGraphics digitizer driver, which instructs users to set the origin in the lower-left corner of the digitizing tablet.)[4]

D_clear_driver( )

This function clears any button presses on the digitizer that have been queued. (Refer to §*21.3 Discussion of the Finer Points (Hints)* [*p. 203*] for an explanation of why this is necessary.) This routine should only return if successful, and should return a value of 0. If it fails, an error message should be sent to the user with *Write_info*(*p. 202*), and the program terminated with a call to *close_down*(*p. 201*).

[4] Due to the design of the GeoGraphics digitizer, it isn't possible to detect whether or not the user properly sets the origin. If the origin is improperly set, the map will be improperly registered.

The following two routines read the current digitizer coordinates:

```
D_read_raw (x, y)
     double  *x, *y ;
```

Gets the current location of the digitizer cursor, and places the digitizer coordinates in the variables **x** and **y.**

If a digitizer button was pressed, this routine returns the button's value. The return value must be in the range of 1 through 16. This means that if the first button is labeled 0 this routine must add 1 to the button number that is returned.

If no button was pressed, this routine returns 0.

Foot-switch. If the digitizer has a foot-switch, instead of cursor buttons, then the foot-switch must be treated as if it were button 1. If the digitizer has neither a foot-switch nor cursor buttons, then this routine should return 0.

```
D_ask_driver_raw (x, y)
     double  *x, *y ;
```

Waits for a button to be pressed and then gets the current location of the digitizer cursor, and places the digitizer coordinates in the variables **x** and **y.**

This routine returns the button's value. The return value must be in the range of 1 through 16. This means that if the first button is labeled 0 this routine must add 1 to the button number that is returned.

Foot-switch. If the digitizer has a foot-switch, instead of cursor buttons, then the foot-switch must be treated as if it were button 1, and this routine should wait for the foot-switch to be pressed. If the digitizer has neither a foot-switch nor cursor buttons, then this routine should return 0 *without* waiting.

21.2.2. Functions Available For Use

There are functions which have already been written that can be called by the digitizer driver. These are described below.

Note. These functions exist in libraries. The libraries that contain these functions are described in §*21.2.3 Compiling the Device Driver* [*p.202*].

```
close_down (status)
        int status ;
```

This function gracefully exits the calling program. Call this function with **status** set to -1 when an irrecoverable error has occurred (e.g., when the digitizer does not respond, or returns an error). Otherwise, call this routine with **status** set to 0.

```
plot_points (type, np, x, y, line_color, point_color)
        int type, np;
        double *x, *y ;
        int line_color, point_color ;
```

This function is to be called by *collect_points*(p. 197). It draws the vector defined by the points in the **x** and **y** arrays on the graphics monitor. The number of points in the vector is **np.**

The *plot_points* ( ) function expects to receive points from *collect_points*(p. 197) in the coordinate system of the database. Digitizer coordinates can be translated to database coordinates using *transform_a_into_b*(p. 201).

The **type** indicates whether the vector is an AREA or a LINE. AREA and LINE are defined in the include file "dig_defines.h".

The **line_color** and **point_color** indicate whether the lines and points are to be highlighted or erased. The constant CLR_HIGHLIGHT indicates highlighting, and the constant CLR_ERASE indicates erase (CLR_HIGHLIGHT and CRL_ERASE are defined in "globals.h"). The colors actually used to highlight or to erase lines and points are specified by the user in *digit.*

```
transform_a_into_b (Xraw, Yraw, X, Y)
        double Xraw, Yraw ;
        double *X, *Y ;
```

This function converts the digitizer coordinates **Xraw,Yraw** into the database coordinates **X,Y.** This function is used by the driver function *collect_points*(p. 197).

Note. The transformation rule used by this routine is generated by *digit* when the user registers the map to the database. The rule is already in place by the time *collect_points*(p. 197) calls *transform_a_into_b* ( ).

```
Write_info (line, message)
        int line ;
        char *message ;
```

This function prints a **message** in the four line window at the bottom of the user's terminal in *digit*. The variable **line** must be a number 1 through 4, which represents the line number inside the window. The **message** must not exceed 76 characters and should not contain \n.

21.2.3. Compiling the Device Driver

Programs (e.g., *digit*) that use the digitizer driver functions are stored in libraries. When the digitizer driver is compiled, it links with those different libraries and creates the programs. Each driver should contain a *Gmakefile* that contains compilation instructions for *Gmake*.[5] The *Gmakefile* for the digitizer driver is complex. Rather than attempting to construct a completely new *Gmakefile*, it is generally simpler to copy an existing *Gmakefile* from another driver and modify it to meet the needs of the new digitizer driver.

The following libraries are needed by the digitizer driver when it is compiled:

```
$GISBASE/src/mapdev/digit/libdigit.a
$GISBASE/src/mapdev/libes/libtrans.a
$GISBASE/src/mapdev/lib/libdig.a
$LIBDIR/libdig_atts.a
```

Some include files (*.h) must also be compiled into the driver. These files are located in the following directories:

```
$GISBASE/src/mapdev/libes
$GISBASE/src/mapdev/lib
```

Compile the device driver by executing *Gmake*. This will create the *digit* program and any other programs dependent on the digitizer driver code.

21.2.4. Testing the Device Driver

There are three crucial points at which the *digit* program calls the digitizer driver. The first occurs just after *digit* has prompted the user for a file name. *Digit* will try to open the driver and initialize the digitizer; if this fails, it is because *D_setup_driver*(*p. 197*) has failed. The second occurs when the user registers the map to the digitizer. If the program fails at this point, there is a problem with the

[5] See §*11 Compiling GRASS Programs Using Gmake* (*p. 55*) for a discussion of *Gmake* and *Gmakefiles*.

D_read_raw(*p.200*) function. A final test of the driver is performed when the *collect_points*(*p.197*) function is called, which occurs when vectors are being digitized.

Before testing any programs, review the *Grass 3.0 Installation Guide* to ensure that the digitizer is set up correctly. If more information is needed, read the file $GISBASE/src/mapdev/README.

21.3. Discussion of the Finer Points (Hints)

This section offers several hints and pitfalls to avoid when writing the digitizer driver. It has three subsections: Setting up the Digitizer, Program Logic, and Specific Driver Issues.

21.3.1. Setting up the Digitizer

The process of setting up a computer system and digitizer can be divided into three steps:

(1) Setting the internal switches on the digitizer (hardware)
(2) Running a cable between the digitizer and the computer (hardware)
(3) Setting up the serial port on the computer (software)

21.3.1.1. Setting the internal switches

The switches on the digitizer must be set so that the digitizer will run under *request* or *prompt* mode, which means that the digitizer will only send output when it is requested or prompted by the program. Thus, the program controls the timing of the output from the digitizer and will only receive information when it is ready to process it. Refer to the manual included with the digitizer for specific information on its set-up.

Note. The digitizer must be able to use an RS232 serial interface and transmit information only when prompted by the program. If the digitizer can't transmit information on command, then it can't be used as a GRASS digitizer.

21.3.1.2. Running a cable between the digitizer and computer

A cable must be made to connect the digitizer to a RS232 serial port on the computer. Different model computers, even when from the same maker, may require different cable configurations. For example, one computer may need a straight-through cable, while another computer may need pins 6, 8, and 20 looped back on the computer side. A break-out box can be used to deduce digitizer cable requirements and ensure that the digitizer is actually talking to the computer.

21.3.1.3. Configuring the serial port

The digitizer is plugged into a serial port (*/dev/tty??*) on the computer, which must be configured for a digitizer to run on it. To set up the *tty* for the digitizer, turn that *tty*'s getty off, and make the *tty* readable and writable by anyone.

A final suggestion: document the information that has been learned. The file *$GISBASE/src/mapdev/digitizers/altek/INSTALL.ALTEK* can be used as an example. It contains the switch settings for the Altek, cable configurations, and other useful information. Such documentation is invaluable when another digitizer is added, problems arise, or if the digitizer switch settings have to be changed because other software is using the digitizer.

21.3.2. Program Logic

All digitizing programs follow the same basic steps, whether they test the digitizer, or appear in a complex digitizing program like *digit*. The following sequence gives the programmer a feel for how the digitizer driver is used by the calling programs.

(1) Link the program to the digitizer (open the *tty*)
(2) Set the *tty* to the appropriate state (ioctl calls)
(3) Initialize the digitizer (setting resolution, setting origin, ...)
(4) Ask the digitizer for data containing a set of coordinates
(5) Read the data from the digitizer
(6) Interpret the data into usable coordinates (x, y)
(7) Display the coordinates (x, y)
(8) Loop back for more data or until user wants to quit

In order to become familiar with the architecture of a digitizer driver, it is useful to write a simple program to test the digitizer. If a digitizing problem arises, the diagnostic program can help isolate the cause of the problem (hardware, software, cable, etc.).

21.3.3. Specific Driver Issues

The writing of digitizer device drivers can be complex. This section explores four issues in greater depth:

(1) Connecting to the digitizer
(2) Initializing and reading the digitizer
(3) Synchronizing the digitizer and computer
(4) Digitizer cursors with buttons

Connecting to the digitizer:

In GRASS 3.0, the computer communicates directly with the digitizer to which (through the serial port *tty*) the digitizer is connected. The *tty* to which the digitizer is connected is opened, read, and written to just like a file.

D_setup_driver(*p. 197*) will open the *tty*, set file permissions to read and write, and set the running state of the *tty*. Some experimenting with the different line disciplines (CBREAK, RAW) may be necessary to determine the best state for the *tty*, but RAW seems to be the norm. Changing the running state of a *tty* consists of changing the structures associated with that particular *tty* and reflecting the changes to the operating system by using *ioctl*( ). Unfortunately, the information is stored differently under different operating systems.

GRASS digitizer drivers have been written under the System V (AT&T) and Berkeley (UCB) UNIX operating systems. A major difference between these two operating systems is the way they handle terminal interfaces (ttys). Terminal information is contained in structures in <termio.h> under System V, and in <sgtty.h> under Berkeley. In other words, the structures, and the names used in the structures, will differ depending on the operating system. All *tty* related system-dependent code has C pre-processor *#ifdef SYSV*[6] statments around it in the existing drivers. System-dependent code is defined as either being under System V (SYSV) or Berkeley. This issue will only arise when the *tty* to which the digitizer is connected is being opened, using *D_setup_driver*(*p. 197*).

Initializing and reading the digitizer:

The driver and the digitizer communicate by using the UNIX *read*( ) and *write*( ) functions. *D_setup_driver*(*p. 197*) sets up the digitizer software by writing command strings to the *tty*. Since each digitizer is different, the digitizer's user manual frequently proves to be the only source of information on how to initialize and read the digitizer.

Setting up a consistently good function to read the digitizer is the most difficult part of writing the digitizer driver. The *read*( ) function, when reading from a *tty*, may not read as many characters as requested. For example, if six bytes are requested, *read*( ) can return anywhere from zero to six bytes.

One approach is to request six bytes, and then, if the number of bytes actually read isn't six, issue another *read*( ), this time asking only for the number of bytes remaining. In other words, if six bytes were requested but only two were received, then another read for four bytes is issued. If that read returned one byte, then another read is requested for three bytes, etc. This would continue until either all six bytes were read, or a time-out occurred. This approach worked well in the Altek driver.

[6] SYSV is defined by *Gmake*. See §*11 Compiling GRASS Programs Using Gmake* (*p. 55*).

Another approach that was tried was to request six bytes, and then, if less than six bytes were received, the bytes were thrown away, and another six bytes were requested. This was repeated until the read returned six bytes. This approach worked some of the time, but sometimes gave unreliable coordinates, and was abandoned. Other digitizer drivers have been written that read ascii characters from the digitizer and use *sscanf*( ) to strip out the needed information.

The number of characters actually read to get one set of coordinates will depend on the digitizer and on the information stated in the digitizer's user manual.

Another problem, in the case of the Altek, is that the cursor is only active in certain portions of the tablet. This means that either there will be no output, or a specific flag will be on/off, until the cursor is within the active area of the tablet. Because no external markings on the tablet delineate the active area, individuals commonly attempt to digitize within the tablet's inactive area, leading them to the false assumption that the digitizer is acting strangely. Depending on the digitizer, this will have to be handled by fine-tuning the reads and/or checking the status byte(s).

A word of warning - if the *tty* isn't set up properly in *D_setup_driver*(*p. 197*), the *read*( ) function can return confusing information (i.e., it may include garbage with the data or be unable to read the number of characters specified).

Synchronizing the digitizer and computer:

Driver-checking has been added to post-3.0 drivers, to warn the user when the driver is out of sync with the digitizer. For example, the Altek has the high bit turned *on* in the first byte of the six bytes that are read. The driver checks to make sure that the high byte is turned *on*; if it is not, the digitizer and driver are out of sync. The driver warns the user, resets the digitizer and then re-initializes the digitizer.

Digitizer cursors with buttons:

Drivers can be written to use the digitizer buttons or the keyboard for input while digitizing. Where drivers use the digitizer buttons, some digitizers will queue up any button hits. (This may depend on what running state the digitizer was set up with when it was initialized.) This means that if a person pushes the digitizer cursor buttons a number of times and then begins to digitize, the program must clear the queue of button hits before beginning to digitize. Other digitizers will only say that a button has been hit if the button has been hit *and* the digitizer has been prompted for a coordinate.

Chapter 22

Writing a Graphics Driver

22.1. Introduction

GRASS 3.0 application programs which use graphics are written with the *Raster Graphics Library*. At compilation time, no actual graphics device driver code is loaded. It is only at run-time that the graphics requests make their way to device-specific code. At run-time, an application program connects with a running graphics *device driver,* typically via system level first-in-first-out (fifo) files. Each GRASS site may have one or more of these programs to choose from. They are managed by the programs *monitor, Dlist.mon, Drelease.mon, Dselect.mon, Dstart.mon, Dstatus.mon, Dstop.mon* and *Dwhich.mon.*

Porting GRASS graphics programs from device to device simply requires the creation of a new graphics driver program. Once completed and working, all GRASS graphics programs will work exactly as they were designed without modification (or recompilation). This section is concerned with the creation of a new graphics driver.

22.2. Basics

The various drivers have source code contained under the directory $GISBASE/src/D/devices.[1] This directory contains a separate directory for each driver, e.g., SUNVIEW and MASS. In addition, the directory *lib* contains files of code which are shared by the drivers. The directory GENERIC contains the beginnings of the required subroutines and sample *Gmakefile.*

A new driver must provide code for this basic set of routines. Once working, the programmer can choose to rewrite some of the generic code to increase the performance of the new driver. Presented first below are the required routines. Suggested options for driver enhancement are then described.

[1] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p 51*] for details.

22.3. Basic Routines

Described here are the basic routines required for constructing a new GRASS 3.0 graphics driver. These routines are all found in the GENERIC directory. It is suggested that the programmer create a new directory (e.g., MYDRIVER) into which all of the GENERIC files are copied (i.e., cp GENERIC/* MYDRIVER).

22.3.1. Open/Close Device

Graph_Set ( ) *initialize graphics*

This routine is called at the start-up of a driver. Any code necessary to establish the desired graphics environment is included here. Often this means clearing the graphics screen, establishing connection with a mouse or pointer, setting drawing parameters, and establishing the dimensions of the drawing screen. In addition, the global integer variables SCREEN_LEFT, SCREEN_RIGHT, SCREEN_TOP, SCREEN_BOTTOM, and NCOLORS must be set. Note that the GRASS software presumes the origin to be in the upper left-hand corner of the screen, meaning:

```
SCREEN_LEFT < SCREEN_RIGHT
SCREEN_TOP  < SCREEN_BOTTOM
```

You may need to flip the coordinate system in your device-specific code to support a device which uses the lower left corner as the origin. These values must map precisely to the screen rows and columns. For example, if the device provides graphics access to pixel columns 2 through 1023, then these values are assigned to SCREEN_LEFT ansd SCREEN_RIGHT, respectively.

NCOLORS is set to the total number of colors available on the device. This most certainly needs to be more than 100 (or so).

Graph_Close ( ) *shut down device*

Close down the graphics processing. This gets called only at driver termination time.

22.3.2. Return Edge and Color Values

The four raster edge values set in the *Graph_Set()* routine above are retrieved with the following routines.

Screen_left (index) *return left pixel column value*
Screen_rite (index) *return right pixel column value*
Screen_top (index) *return top pixel row value*
Screen_bot (index) *return bottom pixel row value*

int *index ;

The requested pixel value is returned in **index.**

These next two routines return the number of colors. There is no good reason for both routines to exist; chalk it up to the power of anachronism.

Get_num_colors (index) *return number of colors*

int *index ;

The number of colors is returned in **index.**

get_num_colors ( ) *return number of colors*

The number of colors is returned directly.

22.3.3. Drawing Routines

The lowest level drawing routines are draw_line( ), which draws a line between two screen coordinates, and Polygon_abs( ) which fills a polygon.

draw_line (x1,y1,x2,y2) *draw a line*

int x1, y1, x2, y2 ;

This routine will draw a line in the current color from **x1,y1** to **x2,y2.**

Polygon_abs (x,y,n) *draw filled polygon*

int *x, *y ;
int n ;

Using the **n** screen coordinate pairs represented by the values in the **x** and **y** arrays, this routine draws a polygon filled with the currently selected color.

22.3.4. Colors

This first routine identifies whether the device allows the run-time setting of device color look-up tables. If it can (and it should), the next two routines set and select colors.

Can_do ( ) *signals run-time color look-up table access*

If color look-up table modification is allowed, then this routine must return 1; otherwise it returns 0. If your device has fixed colors, you must modify the routines in the *lib* directory which set and select colors. Most devices now allow the setting of the color look-up table.

reset_color (number, red, green, blue) *set a color*

```
int number ;
unsigned char red, green, blue ;
```

The system's color represented by **number** is set using the color component intensities found in the **red, green,** and **blue** variables. A value of 0 represents 0% intensity; a value of 255 represents 100% intensity.

color (number) *select a color*

```
int number ;
```

The current color is set to **number.** This number points to the color combination defined in the last call to *reset_color( )* that referenced this number.

22.3.5. Mouse Input

The user provides input through the three following routines.

Get_location_with_box (cx,cy,wx,wy,button) *get location with rubber box*

```
int cx, cy ;
int *wx, *wy ;
int *button ;
```

Using mouse device, get a new screen coordinate and button number. Button numbers must be the following values which correspond to the following software meanings:

1 - left button
2 - middle button
3 - right button

A "rubber-band" box is used. One corner is fixed at the **cx,cy** coordinate. The opposite coordinate starts out at **wx,wy** and then tracks the mouse. Upon button depression, the current coordinate is returned in **wx,wy** and the button pressed is returned in **button.**

Get_location_with_line (cx,cy,wx,wy,button) *get location with rubber line*

```
int cx, cy ;
int *wx, *wy ;
int *button ;
```

Using mouse device, get a new screen coordinate and button number. Button numbers must be the following values which correspond to the following software meanings:

1 - left button
2 - middle button
3 - right button

A "rubber-band" line is used. One end is fixed at the **cx,cy** coordinate. The opposite coordinate starts out at **wx,wy** and then tracks the mouse. Upon button depression, the current coordinate is returned in **wx,wy** and the button pressed is returned in **button**.

Get_location_with_pointer (wx,wy,button) *get location with pointer*

```
int *wx, *wy ;
int *button ;
```

Using mouse device, get a new screen coordinate and button number. Button numbers must be the following values which correspond to the following software meanings:

1 - left button
2 - middle button
3 - right button

A cursor is used which starts out at **wx,wy** and then tracks the mouse. Upon button depression, the current coordinate is returned in **wx,wy** and the button pressed is returned in **button**.

22.3.6. Panels

The following routines cooperate to save and restore sections of the display screen.

Panel_save (name, top, bottom, left, right) *save a panel*

```
    char *name ;
    int top, bottom, left, right ;
```

The bit display between the rows and cols represented by **top, bottom, left,** and **right** are saved. The string pointed to by **name** is a file name which may be used to save the image.

Panel_restore (name) *restore a panel*

```
    char *name ;
```

Place a panel saved in **name** (which is often a file) back on the screen as it was when it was saved. The memory or file associated with **name** is removed.

22.4. Optional Routines

All of the above must be created for any new driver. The GRASS *Rasterlib,* which provides the application program routines which are passed to the driver via the fifo files, contains many more graphics options. There are actually about 44. Above, we have described 19 routines, some of which do not have a counterpart in the *Rasterlib.* For GRASS 3.0, the basic driver library was expanded to accommodate all of the graphics subroutines which could be accomplished at a device-dependent level using the 19 routines described above. This makes driver writing quite easy and straightforward. A price that is paid is that the resulting driver is probably slower and less efficient than it might be if more of the routines were written in a device-dependent way. This section presents a few of the primary target routines that you would most likely consider rewritting for a new driver.

It is suggested that the driver writer copy entire files from the lib area that contain code which shall be replaced. In the loading of libraries during the compilation process, the entire file containing an as yet undefined routine will be loaded. For example, say a file "*ab.c*" contains subroutines a( ) and b( ). Even if the programmer has provided subroutine a( ) elsewhere, at load time, the entire file "*ab.c*" will be loaded to get subroutine b( ). The compiler will likely complain about a mulitply-defined external. To avoid this situation, do not break routines out of their files for modification; modify the entire file.

Raster_int (n, nrows, array, withzeros, type) *raster display*

```
int n ;
int nrows ;
unsigned int *array ;
int withzeros ;
int type ;
```

This is the basic routine for rendering raster images on the screen. Application programs construct images row by row, sending the completed rasters to the device driver. The default *Raster_int()* in lib draws the raster through repetitive calls to *color()* and *draw_line()*. Often a 20x increase in rendering speed is accomplished through low-level raster calls. The raster is found in the **array** pointer. It contains color information for **n** colors and should be repeated for **nrows** rows. Each successive row falls under the previous row. (Depending on the complexity of the raster and the number of rows, it is sometimes advantageous to render the raster through low-level box commands.) The **withzeros** flag indicates whether the zero values should be treated as color 0 (withzeros==1) or as invisible (withzeros==0). Finally, **type** indicates that the raster values are already indexed to the hardware color look-up table (type==0), or that the raster values are indexed to GRASS colors (which must be translated through a look-up table) to hardware look-up table colors (type==1).

Further details on this routine and related routines *Raster_chr()*, and *Raster_def()* are, of course, found in the definitive documentation: the source code.

Chapter 23

Writing a Paint Driver

23.1. Introduction

The *paint* system, which produces hardcopy maps for GRASS, is able to support many different types of color printers. This is achieved by placing all device-dependent code in a separate program called a device driver. Application programs, written using a library of device-independent routines, communicate with the device driver using the UNIX pipe mechanism. The device driver translates the device-independent requests into graphics for the device.

A *paint* driver has two parts: a shell script and an executable program. The executable program is responsible for translating device-independent requests into graphics on the printer. The shell script is responsible for setting some UNIX environment variables that are required by the interface, and then running the executable program.

The user first selects a printer using the *Pselect* program (or the related *paint select* option). The selected printer is stored in the GRASS environment variable PAINTER.[1] Then the user runs one of the application programs. The principal *paint* applications that produce color output are *Pmap* (and the related *paint map* option) which generates scaled maps, and *Pchart* (and the related *paint chart* option) which produces a chart of printer colors. The application looks up the PAINTER and runs the related shell script as a child process. The shell script sets the required environment variables and runs the executable. The application then communicates with the driver via pipes.

[1] See §*10.2 GRASS Environment* [p. 52].

23.2. Creating a Source Directory for the Driver Code

The source code for *paint* drivers lives in

$GISBASE/src/paint/Drivers[2]

Each driver has its own sub-directory containing the source code for the executable program, the shell script, and a *Gmakefile* with rules that tell the GRASS *Gmake* command how to compile the driver.[3]

23.3. The Paint Driver Executable Program

A *paint* device driver program consists of a set of routines (defined below) that perform the device-dependent functions. These routines must be written for each device to be supported.

23.3.1. Printer I/O Routines

The following routines open the printer port and perform low-level i/o to the printer.

Popen (port) *open the printer port*

```
char *port;
```

Open the printer **port** for output. If the **port** is a *tty*, perform any necessary *tty* settings (baud rate, xon/xoff, etc.) required. No data should be written to the **port**.

The **port** will be the value of the UNIX environment variable MAPLP,[4] if set, and NULL otherwise. It is recommended that device drivers use the **port** that is passed to them so that *paint* has a consistent logic.

The baud rate should not be hard-coded into *Popen*( ). It should be set in the driver shell as the UNIX environment variable BAUD. *Popen*( ) should determine the baud rate from this environment variable.

[2] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [p. 51] for details.

[3] See §*11 Compiling GRASS Programs Using Gmake* [p. 55] for details on the GRASS compilation process.

[4] This, and other, environment variables are set in the driver shell script which is described in §*23.4 The Device Driver Shell Script* [p. 222].

Pout (buf, n) *write to printer*

    unsigned char *buf;
    int n;

Output the data in **buf**. The number of bytes to send is **n**. This is a low-level request. No processing of the data is to be done. Output is simply to be sent as is to the printer.

It is not required that data passed to this routine go immediately to the printer. This routine can buffer the output, if desired.

It is recommended that this routine be used to send all output to the printer.

Poutc (c) *write a character to printer*

    unsigned char c;

Send the character **c** to the printer. This routine can be implemented as follows:

```
Poutc(c) unsigned char c;
{
  Pout(c, 1);
}
```

Pouts (s) *write a string to printer*

    unsigned char *s;

Send the character string **s** to the printer. This routine can be implemented as follows:

```
Pouts(s) unsigned char *s;
{
  Pout(s, strlen(s));
}
```

Pflush ( ) *flush pending output*

Flush any pending output to the printer. Do not close the port.

Pclose ( ) *close the printer port*

Flush any pending output to the printer and close the port.

Note. The above routines are usually not device-dependent. In most cases the printer is connected either to a serial *tty* port or to a parallel port. The *paint* driver library[5] contains versions of these routines which can be used for output to either serial or parallel ports. Exceptions to this are the *preview* driver, which sends its output to the graphics monitor, and the *NULL* driver which sends debug output to stderr.

23.3.2. Initialization

The following routine will be called after *Popen(p.216)* to initialize the printer:

Pinit ( ) *initialize the printer*

Initialize the printer. Send whatever codes are necessary to get the printer ready for printing.

23.3.3. Alpha-numeric Mode

The following two routines allow the printer to be used for normal text printing:

Palpha ( ) *put printer in text mode*

Put the printer in alpha-numeric mode. In this mode, the driver should only honor *Ptext(p.218)* calls.

Ptext (text) *print text*

```
char *text;
```

Print the **text** string on the printer.

The **text** will not normally have non-printing characters (i.e., control codes, tabs, linefeeds, returns, etc.) in it. Such characters in the **text** should be ignored or suppressed if they do occur. If the printer requires any linefeeds or carriage returns, this routine should supply them.

Note. If the printer does not have support for text in the hardware, it must be simulated. The *shinko635* printer does not have text, and the code from that driver can be used.

[5] See §*23.6 Paint Driver Library* (*p. 224*).

23.3.4. Graphics Mode

The following routines perform raster color graphics:

Praster ( ) *put printer in graphics mode*

Put the printer in raster graphics mode. This implies that subsequent requests will be related to generating color images on the printer.

Pnpixels (nrows, ncols) *report printer dimensions*

```
int *nrows;
int *ncols;
```

The variable **ncols** should be set to the number of pixels across the printer page. If the driver is combining physical pixels into larger groupings (e.g., 2x2 pixels) to create more colors, then **ncols** should be set the number of these larger pixels.[6]

The variable **nrows** should be set to 0. A non-zero value means that the output media does not support arbitrarily long output and *paint* will scale the output to fit into a window **nrows** *x* **ncols**. The only driver which should set this to a non-zero value is the *preview* driver, which sends its output to the graphics screen.

Ppictsize (nrows, ncols) *defined picture size*

```
int nrows;
int ncols;
```

Prepare the printer for a picture with **nrows** and **ncols**. The number of columns **ncols** will not exceed the number of columns returned by *Pnpixels(p.219)*.[7]

There is no limit on the number of rows **nrows** that will be requested. *Paint* assumes that the printer paper is essentially infinite in length. Some printers (e.g., thermal printers like the *shinko635*) only allow a limited number of rows, after which they leave a gap before the output can begin again. It is up to the driver to handle this. The output will simply have gaps in it. The user will cut out the gaps and tape the pieces back together.

[6] The *Pmap* program cannot make use of more than 1024 pixels. It is acceptable for *Pnpixels*( ) to set **ncols** larger than 1024, but *Pmap* will reset it to 1024. Wide printers will not (currently) be used to their fullest width. When *Pmap* is upgraded, this limitation will disappear.

[7] The programmer should, of course, code defensively. If the number of columns is too large, the driver should exit with an error message.

Pdata (buf, n) *send raster data to printer*

```
unsigned char *buf;
int n;
```

Output the raster data in **buf.** The number of bytes to send is **n,** which will be the *ncols* as specified in the previous call to *Ppictsize(p.219)*. The values in **buf** will be printer color numbers, one per pixel.

Note that the color numbers in **buf** have full color information encoded into them (i.e., red, green, and blue). Some printers (e.g., inkjet) can output all the colors on a row by row basis. Others (e.g., thermal) must lay down a full page of one color, then repeat with another color, etc. Drivers for these printers will have to capture the raster data into temporary files and then make three passes through the captured data, one for each color.

Prle (buf, n) *send rle raster data to printer*

```
unsigned char *buf;
int n;
```

Output the run-length encoded raster data in **buf.** The data is in pairs: *color, count*, where *color* is the raster color to be sent, and *count* is the number of times the *color* is to be repeated (with a *count* of 0 meaning 256). The number of pairs is **n.**

Of course, all the counts should add up to *ncols* as specified in the previous call to *Ppictsize(p.219)*. If the printer can handle run-length encoded data, then the data can be sent either directly or with minimal manipulation. Otherwise, it must be converted into standard raster form before sending it to the printer.

23.3.5. Color Information

The *paint* system expects that the printer has a predefined color table. No attempt is made by *paint* to download a specific color table. Rather, the driver is queried about its available colors. The following routines return information about the colors available on the printer. These routines may be called even if *Popen(p:216)* has not been called.

Pncolors ( ) *number of printer colors*

This routine returns the number of colors available. Currently, this routine must not return a number larger than 255. If the printer is able to generate more than 255 colors, the driver must find a way to select a subset of these colors. Also, the *paint* system works well with printers that have around 125 different colors. If the printer only has three colors (e.g., cyan, yellow, and magenta), then 125 colors can be created using a 2x2 pixel.[8]

Pcolorlevels (red, green, blue) *get color levels*

```
int *red, *green, *blue;
```

Returns the number of colors levels. This means, for example, if the printer has 125 colors, the color level would be 5 for each color; if the printer has 216 colors, the color levels would be 6 for each color, etc.

Pcolornum (red, green, blue) *get color number*

```
float red, green, blue;
```

This routine returns the color number for the printer which most closely approximates the color specified by the **red, green,** and **blue** intensities. These intensities will be in the range 0.0 to 1.0.[9]

The printer color numbers must be in the range 0 to n-1, where n is the number of colors returned by *Pncolors*(*p.221*).

For printers that have cyan, yellow, and magenta instead of red, green and blue, the conversion formulas are:

```
cyan      =   1.0 - red
yellow    =   1.0 - blue
magenta   =   1.0 - green
```

[8] See §*23.8 Creating 125 Colors From 3 Colors* [*p. 227*].

[9] Just to be safe, those above 1.0 can be changed to 1.0, and those below 0.0 can be changed to 0.0.

Pcolorvalue (n, red, green, blue) *get color intensities*

```
  int n;
  float *red, *green, *blue;
```

This routine computes the **red, green,** and **blue** intensities for the printer color number **n**. These intensities must be in the range 0.0 to 1.0. If **n** is not a valid color number, set the intensities to 1.0 (white).

23.4. The Device Driver Shell Script

The driver shell is a small shell script which sets some environment variables, and then executes the driver. The following variables must be set:[10]

MAPLP

This variable should be set to the *tty* port that the printer is on. The *tty* named by this variable is passed to *Popen*(*p.216*). Only in very special cases can drivers justify either ignoring this value or allowing it not to be set.

The drivers distributed by USACERL have MAPLP set to /dev/${PAINTER}. Thus each driver must have a corresponding /dev port. These are normally created as links to real /dev/tty ports.

BAUD

This specifies the baud rate of the output *tty* port. This variable is only needed if the output port is a serial RS-232 tty port. The value of the variable should be an integer (e.g., 1200, 9600, etc.), and should be used by *Popen*(*p.216*) to set the baud rate of the *tty* port.

HRES

This specifies the horizontal resolution of the printer in pixels per inch. This is a positive floating point number.

VRES

This specifies the vertical resolution of the printer in pixels per inch. This is a positive floating point number.

NCHARS

This specifies the maximum number of characters that can be printed on one line in alpha-numeric mode.

Note. The application programs do not try to deduce the width in pixels of text characters.

TEXTSCALE

This positive floating point number is used by *Pmap* and *paint map* to set the size of the numbers placed on the grid when maps are drawn. The normal value

[10] The driver shell script may set any other variables that the programmer has determined the driver needs.

is 1.0, but if the numbers should appear too large, a smaller value (0.75) will shrink these numbers. If they appear too small, a larger value (1.25) will enlarge them. This value must be determined by trial and error.

The next five variables are used to control the color boxes drawn in the map legend for *Pmap* and *paint map*, as well as the boxes for the printer color chart created by *Pchart* and *paint chart*. They have to be determined by trial and error in order to get the numbering to appear under the correct box.[11]

NBLOCKS
This positive integer specifies the maximum number of blocks that are to be drawn per line.

BLOCKSIZE
This positive integer specifies the number of pixels across the top of an individual box.

BLOCKSPACE
This positive integer specifies the number of pixels between boxes.

TEXTSPACE
This positive integer specifies the number of space characters to output after each number (printed under the boxes).

TEXTFUDGE
This non-negative integer provides a way of inserting extra pixels between every other box, or every third box, etc. On some printers, this will not be necessary, in which case TEXTFUDGE should be set to 0. If you find that the numbers under the boxes are drifting away from the intended box, the solution may be to move every other box, or every third box over 1 pixel. For example, to move every other box, set TEXTFUDGE to 2.

The following is a sample *paint* driver shell script:

[11] Apologies are offered for this admittedly awkward design.

```
: ${PAINTER?} ${PAINT_DRIVER?}

MAPLP=/dev/$PAINTER
BAUD=9600

HRES=85.8
VRES=87.0
NCHARS=132

TEXTSCALE=1.0

NBLOCKS=25
BLOCKSIZE=23
BLOCKSPACE=13
TEXTSPACE=1
TEXTFUDGE=3

export MAPLP BAUD HRES VRES NCHARS
export TEXTSCALE TEXTSPACE TEXTFUDGE
export NBLOCKS BLOCKSIZE BLOCKSPACE

exec $PAINT_DRIVER
```

23.5. Programming Considerations

The *paint* driver uses its standard input and standard output to communicate with the *paint* application program. It is very important that neither the driver shell nor the driver program write to stdout or read from stdin.

Diagnostics, error messages, etc., should be written to stderr. There is an error routine which driver programs can use for fatal error messages. It is defined as follows:

```
error (message, perror)
        char *message;
        int perror;
```

This routine prints the **message** on stderr. If **perror** is true (i.e., non-zero), the UNIX routine *perror*( ) will be also called to print a system error message. Finally, *exit*( ) is called to terminate the driver.

23.6. Paint Driver Library

The *paint* system comes with some code that has already be written. This code is in object files under the *paint* driver library directory.[12] These object files are:

[12] See §23.7 *Compiling the Driver* [p. 225] for an example of how to load this library code.

main.o

This file contains the *main*( ) routine **which must be loaded by every driver**, since it contains the code that interfaces with the application programs.

io.o

This file contains versions of *Popen*(*p.216*), *Pout*(*p.217*), *Poutc*(*p.217*), *Pouts*(*p.217*), *Pflush*(*p.217*), and *Pclose*(*p.218*) which can be used with printers that are connected to serial or parallel ports. These routines handle the tricky *tty* interfaces for both System V and Berkeley UNIX, allowing full 8-bit data output to the printer, with xon/xoff control enabled, as well as baud rate selection.

colors125.o

This file contains versions of *Pncolors*(*p.221*), *Pcolorlevels*(*p.221*), *Pcolornum*(*p.221*), and *Pcolorvalue*(*p.222*) for the 125 color logic described in §*23.8 Creating 125 Colors From 3 Colors* [*p.227*].

23.7. Compiling the Driver

Paint drivers are compiled using the GRASS *Gmake* utility which requires a *Gmakefile* containing compilation rules.[13] The following is a sample *Gmakefile*:

[13] See §*11 Compiling GRASS Programs Using Gmake* [*p.55*] for details on the GRASS compilation process.

```
NAME =              sample
DRIVERLIB =         $(SRC)/paint/Interface/driverlib
INTERFACE =         $(DRIVERLIB)/main.o \
                      $(DRIVERLIB)/io.o \
                      $(DRIVERLIB)/colors125.o

DRIVER_SHELL =      $(ETC)/paint/driver.sh/$(NAME)
DRIVER_EXEC =       $(ETC)/paint/driver/$(NAME)

OBJ =               alpha.o  text.o  raster.o  npixels.o \
                      pictsize.o  data.o  rle.o

all: $(DRIVER_EXEC) $(DRIVER_SHELL)

$(DRIVER_EXEC): $(OBJ) $(LOCKLIB)
                    cc $(LDFLAGS) $(INTERFACE) $(OBJ) $(LOCKLIB) -o $@

$(DRIVER_SHELL): DRIVER.sh
                    rm -f $@
                    cp $? $@
                    chmod +x $@

$(OBJ):             P.h
$(LOCKLIB):         # in case library changes
```

There are some features about this *Gmakefile* that should be noted:

printer name (NAME)
: The printer name *sample* is assigned to the NAME variable, which is then used everywhere else.

paint driver library (DRIVERLIB)
: This driver loads code from the common *paint* driver library.[14] It loads *main.o* containing the *main*( ) routine for the driver. **All drivers must load** *main.o*. It loads *io.o* which contains versions of *Popen*(*p.216*), *Pout*(*p.217*), *Poutc*(*p.217*), *Pouts*(*p.217*), *Pflush*(*p.217*), and *Pclose*(*p.218*) for serial and parallel ports. It also loads *colors125.o* which contains versions of *Pncolors*(*p.221*), *Pcolorlevels*(*p.221*), *Pcolornum*(*p.221*), and *Pcolorvalue*(*p.222*) for 125 colors.

lock library (LOCKLIB)
: The driver loads the lock libary. This is a GRASS library which must be loaded if the *Popen*(*p.216*) from the driver library is used.

homes for driver shell and executable
: The driver executable is compiled into the *driver* directory, and the driver shell is copied into the *driver.sh* directory. This means that the driver executable is

[14] See also §*23.6 Paint Driver Library* (*p.224*).

placed in

$GISBASE/etc/paint/driver[15]

and the driver shell in

$GISBASE/etc/paint/driver.sh.

23.8. Creating 125 Colors From 3 Colors

The *paint* system expects that the printer will have a reasonably large number of colors. Some printers support a large color table in the hardware. But others only support three primary colors: red, green, and blue (or cyan, yellow, and magenta). If the printer only has three colors, the driver must simulate more.

If the printer pixels are grouped into 2x2 combinations of pixels, then 125 colors can be simulated. For example, a color with 20% red, 100% green, and 0% blue would have one of the four pixels painted red, all four pixels painted green, and none of the pixels painted blue.

The following code converts [illegible] color intensity in the range 0.0 to 1.0 into a number from 0-4 (i.e., the numb[illegible] pixels to "turn on" for that color):

```
npixels = ( inte[illegible] * 5 ) ;
if (npixels > 4)
  npixels = 4 ;
```

This logic will agree with the 125 color logic used by the *paint* driver library[16] routines *Pncolors*(*p. 221*), *Pcolorlevels*(*p. 221*), *Pcolornum*(*p. 221*), and *Pcolorvalue*(*p. 222*), provided that the color *numbers* are assigned as follows:

```
color_number = red_pixels * 25 + green_pixels * 5 + blue_pixels ;
```

[15] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p. 51*] for details.

[16] See §*23.6 Paint Driver Library* [*p. 224*].

Chapter 24

Writing GRASS Shell Scripts

This section describes some of the things a programmer should consider when writing a shell script that will become a GRASS command.

24.1. Use the Bourne Shell

The Bourne Shell (/bin/sh) is the original UNIX command interpreter. It is available on most (if not all) versions of UNIX. Other command interpreters, such as the C-Shell (/bin/csh), are not as widely available. Therefore, programmers are strongly encouraged to write Bourne Shell scripts for maximum portability.

The discussion that follows is for the Bourne Shell only. It is also assumed that the reader knows (or can learn) how to write Bourne Shell scripts. This chapter is intended to provide guidelines for making them work properly as GRASS commands.

24.2. How a Script Should Start

There are some things that should be done at the beginning of any GRASS shell script:

(1) Verify that the user is running GRASS, and

(2) Cast the GRASS environment variables into the UNIX enviroment,[1] and verify that the variables needed by the shell script are set.

The following accomplishes these two things:

[1] See §*10 Environment Variables* [p. 51]

```
:
if test "$GISRC" = ""
then
   echo "Sorry, you are not running GRASS" >&2
   exit 1
fi
eval `gisenv`
: ${GISBASE?} ${GISDBASE?} ${LOCATION_NAME?} ${MASPET?}
```

Note the use of the : command. This command simply evaluates its arguments. The first use is as the first character of the file, which signals to UNIX that the script is in fact a Bourne Shell script (see §*24.5 Don't Use #!/bin/sh* [*p.231*]). The second use checks to see that variables are set. The syntax ${GISBASE?} means that if GISBASE is not set, issue an error message to standard error and exit the shell script.

24.3. Gask

The GRASS command *Gask* emulates the prompting found in all other GRASS commands, and should be used in shell scripts to ask the user for files from the GRASS database. The user's response can be cast into shell variables. The following example asks the user to select an existing cell file:

```
Gask old "Select a cell file" cell cell /tmp/$$
. /tmp/$$
rm -f /tmp/$$
if test "$name" = ""
then
   exit 0
fi
```

The *Gask* manual entry in the *GRASS User's Reference Manual* describes this command in detail. Here, the reader should note the following:

(1) The temporary file used to hold the user's response is */tmp/$$*. The Bourne Shell will substitute its process id for the *$$* thus creating a unique file name;

(2) The next line, which begins with a dot, sources the commands contained in the temporary file. These commands are:

    name=*something*
    mapset=*something*
    file=*something*

Therefore, the variables $name, $mapset, and $file will contain the name, mapset and full UNIX file name of the cell file selected by the user;

(3) The temporary file is removed; and

(4) If $name is empty, this means that the user changed his or her mind and didn't select any cell file.[2] In this case, something reasonable is done, like

[2] The other variables will be empty as well.

exiting.

24.4. Gfindfile

The *Gfindfile* command can be used to locate GRASS files that were specified as arguments to the shell script (instead of prompted for with *Gask*). Assuming that the variable $request contains the name of a cell file, the following checks to see if the file exists. If it does, the variables $name, $mapset and $file will be set to the name, mapset and full UNIX file name for the cell file:

```
eval `Gfindfile cell "$request"`
if test "$mapset" = ""
then
   echo ERROR: cell file "$request" not found >&2
   exit 1
fi
```

Note. The programmer should use quotes with $request, since it may contain spaces. The user can request a file on the command line of the form "*name* in *mapset*"[3] (quotes will preserve the full request). *Gfindfile* accepts this form and, if found, outputs $name as the name part and $mapset as the mapset part. See the *Gfindfile* manual entry in the *GRASS User's Reference Manual* for more details.

24.5. Don't Use #!/bin/sh

When a user runs a shell script, he or she simply types the name of the shell script just as if it were a compiled program. On systems that have more than one shell, it is the responsibility of UNIX to figure out which shell should interpret the commands in the script. This decision must be made on the basis of the shell for which the script was written.

On systems that have both /bin/sh and /bin/csh, the rule has been: if the first character of the file is #, then the script is given to /bin/csh to interpret; otherwise, it is given to /bin/sh. As the number of shells available grew, the mechanism was expanded to allow the shell script to explicitly specify the interpreter. The rule was modified so that if the first line of the file is:

```
#!command [args]
```

then the *command* (with the specified arguments) is invoked as the script interpreter.

This led to /bin/sh scripts starting with #!/bin/sh. However, the authors have found UNIX systems which do **not** recognize this rule. They simply see the # as the first character, and turn the script over to /bin/csh instead of /bin/sh. Therefore, **scripts for**

[3] This form for GRASS file names is discussed under §*12.5.2 Finding Files in the Database* (p. 70).

/bin/sh should never start with #. A way to start Bourne Shell script that has worked well on all systems with which the authors have experience, is to use the : command (see §*24.2 How a Script Should Start* [*p.229*]).

Appendix A

Annotated Gmake Pre-defined Variables

The pre-defined Gmake variables are defined in the files *makehead* and *make.mid*. These files can be found under $GISBASE/src/CMD.[1]

Note. The variables shown here are described in more detail in §*11 Compiling GRASS Programs Using Gmake* [*p.55*].

makehead

The *makehead* file contains machine-dependent and installation-dependent information. It is created by system personnel when GRASS is installed on a system prior to compilation. This file varies from system to system.

[1] $GISBASE is the directory where GRASS is installed. See §*10.1 UNIX Environment* [*p.51*] for details.

Annotated sample *makehead* file

Variable	Value	Description
GIS	= /grass	GRASS installation directory
GISDBASE	= /grass/data	GRASS database directory
UNIX_BIN	= /usr/local/bin	UNIX command bin directory
DEFAULT_LOCATION	= spearfish	Default Location for new users
OS	= SYSV	Tty interface flag
#OS	= BERK	
COMPILE_FLAGS	= -O	Compiler options
LDFLAGS	= -s	Loader options
DIGIT_FLAGS	=	Digitizer compile time flag
#DIGIT_FLAGS	= -DATT	
#DIGIT_FLAGS	= -DMASSCOMP	
MATHLIB	= -lm	Math library
TERMLIB	= -ltermlib	Termlib/termcap library
CLEAR	= ok	Can use termlib to clear screen
#CLEAR	= no	
AR	= ar ruv $@ $?;\ ranlib $@	Library archive rule for systems with ranlib
#AR	= ar rc $@\ 'lorder $(OBJ) | tsort'	Library archive rule for systems without ranlib

make.mid

The *make.mid* file uses the variables in *makehead* to construct other variables that are useful for compilation rules. The contents of this file are usually unchanged from system to system.

Annotated *make.mid* file

Variable	Value	Description
CFLAGS	= $(COMPILE_FLAGS) -I$(LIBDIR)\ -D$(OS) $(EXTRA_CFLAGS)	Compiler flags
GMAKE	= $(GIS)/src/CMD/Gmake	Gmake command
MAKEALL	= set - *; for d do\ test -f $$d/Gmakefile && $(GMAKE) $$d;\ done; exit 0	Gmake "all"
MANROFF	= tbl -TX \ $(GIS)/src/man.help/man.header $?\ | nroff -Tlp | col -b > $@	Nroff rule for manual pages
CURSES	= -lcurses $(TERMLIB)	Curses libraries
MAN1	= $(GIS)/man/1	Man directory, section 1
MAN2	= $(GIS)/man/2	Man directory, section 2
HELP	= $(GIS)/man/help	Help directory
BIN	= $(GIS)/bin	GRASS command directory
ETC	= $(GIS)/etc	GRASS command support directory
SRC	= $(GIS)/src	GRASS source directory
LIBDIR	= $(GIS)/src/libes	GRASS library directory
GISLIB	= $(LIBDIR)/libgis.a	GIS library
IMAGERYLIB	= $(LIBDIR)/libI.a	Imagery library
LOCKLIB	= $(LIBDIR)/liblock.a	Lock library
SEGMENTLIB	= $(LIBDIR)/libsegment.a	Segment library
DLGLIB	= $(LIBDIR)/libdlg.a	Dlg library
RASTERLIB	= $(SRC)/D/libes/rasterlib.a	Raster library
DISPLAYLIB	= $(SRC)/D/libes/displaylib.a	Display library
VASKLIB	= $(LIBDIR)/libvask.a	Vask library
VASK	= $(VASKLIB) $(CURSES)	Vask + curses library

Appendix B

The CELL Data Type

GRASS cell file data is defined to be of type CELL. This data type is defined in the "gis.h" header file. Programmers must declare all variables and buffers which will hold cell file data or category codes (which are CELL values as well) as type CELL.

Under GRASS 3.0 the CELL data type is declared to be *int,* but the programmer should not assume this. What should be assumed is that CELL is a signed integer type. It may be changed sometime to *short* or *long*. This implies that use of CELL data with routines which do not know about this data type (e.g., printf( ), sscanf( ), etc.) must use an intermediate variable of type *long*.

To print a CELL value, it must be cast to *long*. For example:

```
CELL c;                     /* cell value to be printed */

                            /* some code to get a value for c */

printf ("%ld\n", (long) c); /* cast c to long to print */
```

To read a CELL value, for example from user-typed input, it is necessary to read into a *long* variable, and then assign it to the CELL variable. For example:[1]

```
char userbuf[128];
CELL c;
long x;

printf ("Which category? ");  /* prompt user */
gets(userbuf);                /* get user response */
sscanf (userbuf,"%ld", &x);   /* scan category into long variable */
c = (CELL) x;                 /* assign long value to CELL value */
```

Of course, with GRASS library routines that are designed to handle the CELL type, this problem does not arise. It is only when CELL data must be used in routines which don't know about the CELL type, that the values must be cast to or from *long*.

[1] This example does not check for valid inputs, EOF, etc., which good code must do.

Appendix C

Index to GIS Library

Here is an index of GIS Library routines, with calling sequences and short function descriptions.

GIS Library

routine	parameters	description	page
G_allocate_cell_buf	()	allocate a cell buffer	86
G_ask_any	(prompt, name, element, label, warn)	prompt for any valid file name	70
G_ask_cell_in_mapset	(prompt, name)	prompt for existing cell file	81
G_ask_cell_new	(prompt, name)	prompt for new cell file	81
G_ask_cell_old	(prompt, name)	prompt for existing cell file	81
G_ask_in_mapset	(prompt, name, element, label)	prompt for existing database file	70
G_ask_new	(prompt, name, element, label)	prompt for new database file	69
G_ask_old	(prompt, name, element, label)	prompt for existing database file	69
G_ask_sites_in_mapset	(prompt, name)	prompt for existing site list file	106
G_ask_sites_new	(prompt, name)	prompt for new site list file	106
G_ask_sites_old	(prompt, name)	prompt for existing site list file	106
G_ask_vector_in_mapset	(prompt, name)	prompt for an existing vector file	101
G_ask_vector_new	(prompt, name)	prompt for a new vector file	101
G_ask_vector_old	(prompt, name)	prompt for an existing vector file	101
G_calloc	(n, size)	memory allocation	76
G_close_cell	(fd)	close a cell file	89
G_date	()	current date and time	117
G_fatal_error	(message)	print error message and exit	64
G_find_cell2	(name, mapset)	find a cell file	82
G_find_cell	(name, mapset)	find a cell file	82
G_find_file2	(element, name, mapset)	find a database file	71
G_find_file	(element, name, mapset)	find a database file	71
G_find_vector2	(name, mapset)	find a vector file	102
G_find_vector	(name, mapset)	find a vector file	102
G_fopen_append	(element, name)	open a database file for update	73
G_fopen_new	(element, name)	open a new database file	74
G_fopen_old	(element, name, mapset)	open a database file for reading	73
G_fopen_sites_new	(name)	open a new site list file	107
G_fopen_sites_old	(name, mapset)	open an existing site list file	107
G_fopen_vector_new	(name)	open a new vector file	104
G_fopen_vector_old	(name, mapset)	open an existing vector file	103
G_fork	()	create a protected child process	116
G_free_cats	(cats)	free category structure memory	94
G_free_colors	(colors)	free color structure memory	96
G_get_ask_return_msg	()	get Hit RETURN msg	70
G_get_cat	(n, cats)	get a category label	93
G_get_cats_title	(cats)	get title from category structure	93
G_get_cellhd	(name, mapset, cellhd)	read the cell header	90
G_get_cell_title	(name, mapset)	get cell title	92
G_get_color	(cat, red, green, blue, colors)	get a category color	95
G_get_default_window	(window)	read the default window	78

GIS Library

routine	parameters	description	page
G__getenv	(name)	query GRASS environment variable	67
G_getenv	(name)	query GRASS environment variable	67
G_get_map_row	(fd, cell, row)	read a cell file	87
G_get_map_row_nomask	(fd, cell, row)	read a cell file (without masking)	87
G_gets	(buf)	get a line of input (detect ctrl-z)	117
G_get_set_window	(window)	get the active window	79
G_get_site	(fd, east, north, desc)	read site list file	107
G_get_window	(window)	read the database window	77
G_gisbase	()	top level program directory	66
G_gisdbase	()	top level database directory	67
G_gisinit	(program_name)	initialize gis library	64
G_home	()	user's home directory	117
G_init_cats	(n, title, cats)	initialize category structure	93
G_init_colors	(colors)	initialize color structure	96
G_init_range	(range)	initialize range structure	100
G_intr_char	()	return interrupt char	117
G_is_reclass	(name, mapset, r_name, r_mapset)	reclass file?	91
G_legal_filename	(name)	check for legal database file names	72
G_location	()	current location name	66
G_location_path	()	current location directory	67
G_make_aspect_colors	(colors, min, max)	make aspect colors	97
G_make_color_ramp	(colors, min, max)	make color ramp	97
G_make_color_wave	(colors, min, max)	make color wave	97
G_make_grey_scale	(colors, min, max)	make linear grey scale	97
G_make_rainbow_colors	(colors, min, max)	make rainbow colors	97
G_make_random_colors	(colors, min, max)	make random colors	98
G_make_red_yel_grn	(colors, min, max)	make red,yellow,green colors	98
G_malloc	(size)	memory allocation	76
G_mapset	()	current mapset name	66
G_myname	()	location title	66
G_open_cell_new	(name)	open a new cell file (sequential)	84
G_open_cell_new_random	(name)	open a new cell file (random)	85
G_open_cell_new_uncompressed	(name)	open a new cell file (uncompressed)	85
G_open_cell_old	(name, mapset)	open an existing cell file	83
G_open_new	(element, name)	open a new database file	74
G_open_old	(element, name, mapset)	open a database file for reading	72
G_open_update	(element, name)	open a database file for update	73
G_parse_command	(argc, argv, keys, stash)	parse command line	109
G_parse_command_usage	(program, keys, format)	command line usage message	111
G_percent	(n, total, incr)	print percent complete messages	117
G_program_name	()	return program name	118
G_projection_name	(proj)	query cartographic projection	80
G_projection	()	query cartographic projection	80
G_put_cellhd	(name, cellhd)	write the cell header	90
G_put_cell_title	(name, title)	change cell title	92
G_put_map_row	(fd, buf)	write a cell file (sequential)	88
G_put_map_row_random	(fd, buf, row, col, ncells)	write a cell file (random)	88
G_put_site	(fd, east, north, desc)	write site list file	108
G_put_window	(window)	write the database window	77
G_read_cats	(name, mapset, cats)	read cell category file	91
G_read_colors	(name, mapset, colors)	read map layer color table	94

GIS Library

Appendix D

Index to Dig Library

Here is an index of Dig Library routines, with calling sequences and short function descriptions.

Dig Library

routine	parameters	description	page
dig_bound_box	(p, N, S, E, W)	get arc bounding box	135
dig_check_dist	(map, n, x, y, d)	distance to arc	132
dig_distance2_point_to_line	(x, y, x1, y1, x2, y2)	distance to line-segment	134
dig_fini	(fd)	end level one vector access	125
dig_init_box	(N, S, E, W)	limit arc search in box	127
dig_init	(fd)	initialize level one vector access	125
dig_P_area_att	(map, n)	get area category attribute	130
dig_P_fini	(map)	end level two vector access	128
dig_P_get_area_bbox	(map, n, N, S, E, W)	get area bounding box	130
dig_P_get_area	(map, n, pa)	get area polygon	129
dig_P_get_area_xy	(map, n, np, x, y)	get area polygon	129
dig_P_get_line_bbox	(map, n, N, S, E, W)	get arc bounding box	131
dig_P_init	(name, mapset, map)	initialize level two vector access	128
dig_P_line_att	(map, n)	get arc category attribute	131
dig_P_num_areas	(map)	get number of areas	129
dig_P_num_lines	(map)	get number of arcs	130
dig_point_in_area	(map, x, y, pa)	point in area	132
dig_point_to_area	(map, x, y)	find area with point	132
dig_point_to_line	(map, x, y, type)	find arc with point	132
dig_P_read_line	(map, n, p)	read arc	130
dig_P_read_next_line	(map, p)	read next arc	131
dig_P_rewind	(map)	rewind next-arc pointer .	131
dig_print_header	( )	display vector header information	125
dig_prune	(p, threshold)	prune a dense arc	135
dig_P_tmp_close	(map)	temporary close vector map	128
dig_P_tmp_open	(map)	reopen closed vector map	128
dig_read_head_binary	(fd, header)	read vector header	134
dig_Read_line	(fd, offset, x, y, np)	read arc	133
dig_read_line_in_box	(fd, np, x, y)	read arc in box	127
dig_read_next_line	(fd, np, x, y)	get next arc	126
dig_read_next_line_type	(fd, np, x, y, type)	get next arc by type	126
dig_rewind	(fd)	rewind vector file	125
dig_write_head_binary	(fd, header)	write vector header	134
dig_Write_line	(fd, type, x, y, np)	write arc	133
dig_xy_distance2_point_to_line	(x,y,x1,y1,x2,y2)	distance to line-segment	135

Appendix E

Index to Imagery Library

Here is an index of Dig Imagery routines, with calling sequences and short function descriptions.

Dig Imagery

routine	parameters	description	page
dig_bound_box	(p, N, S, E, W)	get arc bounding box	135
dig_check_dist	(map, n, x, y, d)	distance to arc	132
dig_distance2_point_to_line	(x, y, x1, y1, x2, y2)	distance to line-segment	134
dig_fini	(fd)	end level one vector access	125
dig_init_box	(N, S, E, W)	limit arc search in box	127
dig_init	(fd)	initialize level one vector access	125
dig_P_area_att	(map, n)	get area category attribute	130
dig_P_fini	(map)	end level two vector access	128
dig_P_get_area_bbox	(map, n, N, S, E, W)	get area bounding box	130
dig_P_get_area	(map, n, pa)	get area polygon	129
dig_P_get_area_xy	(map, n, np, x, y)	get area polygon	129
dig_P_get_line_bbox	(map, n, N, S, E, W)	get arc bounding box	131
dig_P_init	(name, mapset, map)	initialize level two vector access	128
dig_P_line_att	(map, n)	get arc category attribute	131
dig_P_num_areas	(map)	get number of areas	129
dig_P_num_lines	(map)	get number of arcs	130
dig_point_in_area	(map, x, y, pa)	point in area	132
dig_point_to_area	(map, x, y)	find area with point	132
dig_point_to_line	(map, x, y, type)	find arc with point	132
dig_P_read_line	(map, n, p)	read arc	130
dig_P_read_next_line	(map, p)	read next arc	131
dig_P_rewind	(map)	rewind next-arc pointer	131
dig_print_header	( )	display vector header information	125
dig_prune	(p, threshold)	prune a dense arc	135
dig_P_tmp_close	(map)	temporary close vector map	128
dig_P_tmp_open	(map)	reopen closed vector map	128
dig_read_head_binary	(fd, header)	read vector header	134
dig_Read_line	(fd, offset, x, y, np)	read arc	133
dig_read_line_in_box	(fd, np, x, y)	read arc in box	127
dig_read_next_line	(fd, np, x, y)	get next arc	126
dig_read_next_line_type	(fd, np, x, y, type)	get next arc by type	126
dig_rewind	(fd)	rewind vector file	125
dig_write_head_binary	(fd, header)	write vector header	134
dig_Write_line	(fd, type, x, y, np)	write arc	133
dig_xy_distance2_point_to_line	(x,y,x1,y1,x2,y2)	distance to line-segment	135

Appendix F

Index to Display Graphics Library

Here is an index of Display Graphics Library routines, with calling sequences and short function descriptions.

Display Graphics Library

routine	parameters	description	page
D_add_to_list	(string)	add command to window display list	161
D_a_to_d_col	(column)	array to screen (column)	163
D_a_to_d_row	(row)	array to screen (row)	163
D_cell_draw_setup	(top, bottom, left, right)	prepare for raster graphics	165
D_check_map_window	(window)	assign/retrieve current map window	160
D_clear_window	()	clear window display lists	161
D_clear_window	()	clears information about current window	161
D_clip	(s, n, w, e, x, y, c_x, c_y)	clip coordinates to window	166
D_do_conversions	(window, top, bottom, left, right)	initialize conversions	162
D_draw_cell_row	(row, raster)	render a raster row	165
D_d_to_a_col	(x)	screen to array (x)	164
D_d_to_a_row	(y)	screen to array (y)	164
D_d_to_u_col	(x)	screen to earth (x)	164
D_d_to_u_row	(y)	screen to earth (y)	164
D_erase_window	()	erase current window	161
D_get_cell_name	(name)	retrieve cell file name	162
D_get_cur_wind	(name)	identify current graphics window	160
D_get_screen_window	(top, bottom, left, right)	retrieve current window coordinates	160
D_new_window	(name, top, bottom, left, right)	create new graphics window	160
D_overlay_cell_row	(row, raster)	render a raster row without zeros	165
D_popup	(bcolor, tcolor, dcolor, top, left, size, options)	pop-up menu	166
D_remove_window	()	remove a window	161
D_reset_colors	(colors)	set colors in driver	167
D_reset_screen_window	(top, bottom, left, right)	resets current window position	161
D_set_cell_name	(name)	add cell file name to display list	162
D_set_cur_wind	(name)	set current graphics window	160
D_show_window	(color)	outlines current window	160
D_timestamp	()	give current time to window	161
D_translate_color	(name)	color name to number	167
D_u_to_a_col	(east)	earth to array (east)	163
D_u_to_a_row	(north)	earth to array (north)	163
D_u_to_d_col	(east)	earth to screen (east)	164
D_u_to_d_row	(north)	earth to screen (north)	163

Appendix G

Index to Raster Graphics Library

Here is an index of Raster Graphics Library routines, with calling sequences and short function descriptions.

Raster Graphics Library

routine	parameters	description	page
R_box_abs	(x1,y1,x2,y2)	fill a box	151
R_box_rel	(dx,dy)	fill a box	151
R_close_driver	( )	terminate graphics	148
R_color	(color)	select color	149
R_color_table_fixed	( )	select fixed color table	149
R_color_table_float	( )	select floating color table	149
R_cont_abs	(x,y)	draw line	151
R_cont_rel	(dx,dy)	draw line	151
R_erase	( )	erase screen	152
R_flush	( )	flush graphics	152
R_font	(font)	choose font	155
R_get_location_with_box	(x,y,nx,ny,button)	get mouse location using a box	157
R_get_location_with_line	(x,y,nx,ny,button)	get mouse location using a line	156
R_get_location_with_pointer	(nx,ny,button)	get mouse location using pointer	156
R_get_text_box	(text, top, bottom, left, right)	get text extents	156
R_move_abs	(x,y)	move current location	150
R_move_rel	(dx,dy)	move current location	151
R_open_driver	( )	initialize graphics	148
R_polydots_abs	(x,y,num)	draw a series of dots	152
R_polydots_rel	(x,y,num)	draw a series of dots	152
R_polygon_abs	(x,y,num)	draw a closed polygon	152
R_polygon_rel	(x,y,num)	draw a closed polygon	153
R_polyline_abs	(x,y,num)	draw an open polygon	153
R_polyline_rel	(x,y,num)	draw an open polygon	153
R_raster	(num,nrows,withzero,raster)	draw a raster	154
R_reset_color	(red, green, blu, num)	define single color	149
R_reset_colors	(min,max,red,green,blue)	define multiple colors	149
R_RGB_color	(red,green,blue)	select color	150
R_RGB_raster	(num,nrows,red,green,blue,withzero)	draw a raster	154
R_screen_bot	( )	bottom of screen	150
R_screen_left	( )	screen left edge	150
R_screen_rite	( )	screen right edge	150
R_screen_top	( )	top of screen	150
R_set_RGB_color	(red,green,blue)	initialize graphics	154
R_set_window	(top,bottom,left,right)	set text clipping window	155
R_standard_color	(color)	select standard color	150
R_text_size	(width, height)	set text size	155
R_text	(text)	write text	156

Appendix H

Index to Rowio Library

Here is an index of Rowio Library routines, with calling sequences and short function descriptions.

Rowio Library

routine	parameters	description	page
rowio_fileno	(r)	get file descriptor	176
rowio_flush	(r)	force pending updates to disk	176
rowio_forget	(r, n)	forget a row	175
rowio_get	(r, n)	read a row	175
rowio_put	(r, buf, n)	write a row	176
rowio_release	(r)	free allocated memory	176
rowio_setup	(r, fd, nrows, len, getrow, putrow)	configure rowio structure	174

Appendix I

Index to Segment Library

Here is an index of Segment Library routines, with calling sequences and short function descriptions.

Segment Library

routine	parameters	description	page
segment_flush	(seg)	flush pending updates to disk	182
segment_format	(fd, nrows, ncols, srows, scols, len)	format a segment file	180
segment_get_row	(seg, buf, row)	read row from segment file	182
segment_get	(seg, value, row, col)	get value from segment file	181
segment_init	(seg, fd, nsegs)	initialize segment structure	181
segment_put_row	(seg, buf, row)	write row to segment file	181
segment_put	(seg, value, row, col)	put value to segment file	182
segment_release	(seg)	free allocated memory	183

Appendix J

Index to Vask Library

Here is an index of Vask Library routines, with calling sequences and short function descriptions.

Vask Library

routine	parameters	description	page
V_call	( )	interact with the user	189
V_clear	( )	initialize screen description	188
V_const	(value, type, row, col, len)	define screen constant	188
V_float_accuracy	(num)	set number of decimal places	189
V_intrpt_msg	(text)	change ctrl-c message	190
V_intrpt_ok	( )	allow ctrl-c	189
V_line	(num, text)	add line of text to screen	188
V_ques	(value, type, row, col, len)	define screen question	188

Appendix K

Permuted Index for Library Subroutines

end level one vector	access	dig_fini()	125
initialize level one vector	access	dig_init()	125
end level two vector	access	dig_P_fini()	128
initialize level two vector	access	dig_P_init()	128
get the	active window	G_get_set_window()	79
set the	active window	G_set_window()	79
number of columns in	active window	G_window_cols()	78
number of rows in	active window	G_window_rows()	78
	add cell file name to display list	D_set_cell_name()	162
	add command to window display list	D_add_to_list()	161
	add file name to Ref structure	I_add_file_to_group_ref()	141
	add line of text to screen	V_line()	188
	add new control point	I_new_control_point()	143
	allocate a cell buffer	G_allocate_cell_buf()	86
copy string to	allocated memory	G_store()	114
free	allocated memory	rowio_release()	176
free	allocated memory	segment_release()	183
memory	allocation	G_calloc()	76
memory	allocation	G_malloc()	76
memory	allocation	G_realloc()	76
	allow ctrl-c	V_intrpt_ok()	189
distance to	arc	dig_check_dist()	132
read	arc	dig_P_read_line()	130
read next	arc	dig_P_read_next_line()	131
prune a dense	arc	dig_prune()	135
read	arc	dig_Read_line()	133
get next	arc	dig_read_next_line()	126
write	arc	dig_Write_line()	133
get	arc bounding box	dig_bound_box()	135
get	arc bounding box	dig_P_get_line_bbox()	131
get next	arc by type	dig_read_next_line_type()	126
get	arc category attribute	dig_P_line_att()	131
read	arc in box	dig_read_line_in_box()	127
limit	arc search in box	dig_init_box()	127
find	arc with point	dig_point_to_line()	132
get number of	arcs	dig_P_num_lines()	130
point in	area	dig_point_in_area()	132
get	area bounding box	dig_P_get_area_bbox()	130
get	area category attribute	dig_P_area_att()	130
get	area polygon	dig_P_get_area()	129
get	area polygon	dig_P_get_area_xy()	129
find	area with point	dig_point_to_area()	132
get number of	areas	dig_P_num_areas()	129
earth to	array (east)	D_u_to_a_col()	163
earth to	array (north)	D_u_to_a_row()	163
	array to screen (column)	D_a_to_d_col()	163
	array to screen (row)	D_a_to_d_row()	163
screen to	array (x)	D_d_to_a_col()	164

screen to	array (y)	D_d_to_a_row( )	164
	ask a yes/no question	G_yes( )	118
make	aspect colors	G_make_aspect_colors( )	97
	assign/retrieve current map window	D_check_map_window( )	160
get area category	attribute	dig_P_area_att( )	130
get arc category	attribute	dig_P_line_att( )	131
	bottom of screen	R_screen_bot( )	150
get arc	bounding box	dig_bound_box( )	135
get area	bounding box	dig_P_get_area_bbox( )	130
get arc	bounding box	dig_P_get_line_bbox( )	131
get arc bounding	box	dig_bound_box( )	135
limit arc search in	box	dig_init_box( )	127
get area bounding	box	dig_P_get_area_bbox( )	130
get arc bounding	box	dig_P_get_line_bbox( )	131
read arc in	box	dig_read_line_in_box( )	127
fill a	box	R_box_abs( )	151
fill a	box	R_box_rel( )	151
get mouse location using a	box	R_get_location_with_box( )	157
allocate a cell	buffer	G_allocate_cell_buf( )	86
zero a cell	buffer	G_zero_cell_buf( )	86
query	cartographic projection	G_projection( )	80
query	cartographic projection	G_projection_name( )	80
query	cartographic zone	G_zone( )	80
convert string to lower	case	G_tolcase( )	114
convert string to upper	case	G_toucase( )	114
get area	category attribute	dig_P_area_att( )	130
get arc	category attribute	dig_P_line_att( )	131
get a	category color	G_get_color( )	95
set a	category color	G_set_color( )	96
read cell	category file	G_read_cats( )	91
read vector	category file	G_read_vector_cats( )	105
write cell	category file	G_write_cats( )	92
write vector	category file	G_write_vector_cats( )	105
get a	category label	G_get_cat( )	93
set a	category label	G_set_cat( )	94
get title from	category structure	G_get_cats_title( )	93
initialize	category structure	G_init_cats( )	93
set title in	category structure	G_set_cats_title( )	94
free	category structure memory	G_free_cats( )	94
allocate a	cell buffer	G_allocate_cell_buf( )	86
zero a	cell buffer	G_zero_cell_buf( )	86
read	cell category file	G_read_cats( )	91
write	cell category file	G_write_cats( )	92
prompt for existing	cell file	G_ask_cell_in_mapset( )	81
prompt for new	cell file	G_ask_cell_new( )	81
prompt for existing	cell file	G_ask_cell_old( )	81
close a	cell file	G_close_cell( )	89
find a	cell file	G_find_cell2( )	82
find a	cell file	G_find_cell( )	82
read a	cell file	G_get_map_row( )	87
open an existing	cell file	G_open_cell_old( )	83
unopen a	cell file	G_unopen_cell( )	89
retrieve	cell file name	D_get_cell_name( )	162
add	cell file name to display list	D_set_cell_name( )	162

run a shell level	command	G_system()	116
parse	command line	G_parse_command()	109
	command line usage message	G_parse_command_usage()	111
add	command to window display list	D_add_to_list()	161
print percent	complete messages	G_percent()	117
	concatentate strings	G_strcat()	113
	configure rowio structure	rowio_setup()	174
define screen	constant	V_const()	188
print warning message and	continue	G_warning()	64
printable version of	control character	G_unctrl()	114
add new	control point	I_new_control_point()	143
read group	control points	I_get_control_points()	143
write group	control points	I_put_control_points()	144
initialize	conversions	D_do_conversions()	162
	convert string to lower case	G_tolcase()	114
	convert string to upper case	G_toucase()	114
retrieve current window	coordinates	D_get_screen_window()	160
clip	coordinates to window	D_clip()	166
	copy Ref lists	I_transfer_group_ref_file()	141
	copy string to allocated memory	G_store()	114
	copy strings	G_strcpy()	113
	copy strings	G_strncpy()	113
	create a lock	lock_file()	169
	create a protected child process	G_fork()	116
	create new graphics window	D_new_window()	160
allow	ctrl-c	V_intrpt_ok()	189
change	ctrl-c message	V_intrpt_msg()	190
get a line of input (detect	ctrl-z)	G_gets()	117
	current date and time	G_date()	117
identify	current graphics window	D_get_cur_wind()	160
set	current graphics window	D_set_cur_wind()	160
move	current location	R_move_abs()	150
move	current location	R_move_rel()	151
	current location directory	G_location_path()	67
	current location name	G_location()	66
assign/retrieve	current map window	D_check_map_window()	160
	current mapset name	G_mapset()	66
give	current time to window	D_timestamp()	161
clears information about	current window	D_clear_window()	161
erase	current window	D_erase_window()	161
outlines	current window	D_show_window()	160
retrieve	current window coordinates	D_get_screen_window()	160
resets	current window position	D_reset_screen_window()	161
top level	database directory	G_gisdbase()	67
prompt for existing	database file	G_ask_in_mapset()	70
prompt for new	database file	G_ask_new()	69
prompt for existing	database file	G_ask_old()	69
find a	database file	G_find_file2()	71
find a	database file	G_find_file()	71
open a new	database file	G_fopen_new()	74
open a new	database file	G_open_new()	74
remove a	database file	G_remove()	75
rename a	database file	G_rename()	75
open a	database file for reading	G_fopen_old()	73

open a	database file for reading	G_open_old( )	72
open a	database file for update	G_fopen_append( )	73
open a	database file for update	G_open_update( )	73
check for legal	database file names	G_legal_filename( )	72
read the	database window	G_get_window( )	77
write the	database window	G_put_window( )	77
current	date and time	G_date( )	117
set number of	decimal places	V_float_accuracy( )	189
read the	default window	G_get_default_window( )	78
	define multiple colors	R_reset_colors( )	149
	define screen constant	V_const( )	188
	define screen question	V_ques( )	188
	define single color	R_reset_color( )	149
prune a	dense arc	dig_prune( )	135
initialize screen	description	V_clear( )	188
get file	descriptor	rowio_fileno( )	176
get a line of input	(detect ctrl-z)	G_gets( )	117
top level program	directory	G_gisbase( )	66
top level database	directory	G_gisdbase( )	67
user's home	directory	G_home( )	117
current location	directory	G_location_path( )	67
force pending updates to	disk	rowio_flush( )	176
flush pending updates to	disk	segment_flush( )	182
add command to window	display list	D_add_to_list( )	161
add cell file name to	display list	D_set_cell_name( )	162
clear window	display lists	D_clear_window( )	161
	display vector header information	dig_print_header( )	125
	distance to arc	dig_check_dist( )	132
	distance to line-segment	dig_distance2_point_to_line( )	134
	distance to line-segment	dig_xy_distance2_point_to_line( )	135
	does group exist?	I_find_group( )	139
draw a series of	dots	R_polydots_abs( )	152
draw a series of	dots	R_polydots_rel( )	152
	draw a closed polygon	R_polygon_abs( )	152
	draw a closed polygon	R_polygon_rel( )	153
	draw a raster	R_raster( )	154
	draw a raster	R_RGB_raster( )	154
	draw a series of dots	R_polydots_abs( )	152
	draw a series of dots	R_polydots_rel( )	152
	draw an open polygon	R_polyline_abs( )	153
	draw an open polygon	R_polyline_rel( )	153
	draw line	R_cont_abs( )	151
	draw line	R_cont_rel( )	151
set colors in	driver	D_reset_colors( )	167
	earth to array (east)	D_u_to_a_col( )	163
	earth to array (north)	D_u_to_a_row( )	163
	earth to screen (east)	D_u_to_d_col( )	164
	earth to screen (north)	D_u_to_d_row( )	163
screen to	earth (x)	D_d_to_u_col( )	164
screen to	earth (y)	D_d_to_u_row( )	164
earth to array	(east)	D_u_to_a_col( )	163
earth to screen	(east)	D_u_to_d_col( )	164
screen left	edge	R_screen_left( )	150
screen right	edge	R_screen_rite( )	150

	end level one vector access	dig_fini( )	125
	end level two vector access	dig_P_fini( )	128
query GRASS	environment variable	G__getenv( )	67
query GRASS	environment variable	G_getenv( )	67
set GRASS	environment variable	G__setenv( )	67
set GRASS	environment variable	G_setenv( )	67
	erase current window	D_erase_window( )	161
	erase screen	R_erase( )	152
sleep on	error?	G_sleep_on_error( )	65
change	error handling	G_set_error_routine( )	65
reset normal	error handling	G_unset_error_routine( )	65
print	error message and exit	G_fatal_error( )	64
does group	exist?	I_find_group( )	139
prompt for	existing cell file	G_ask_cell_in_mapset( )	81
prompt for	existing cell file	G_ask_cell_old( )	81
open an	existing cell file	G_open_cell_old( )	83
prompt for	existing database file	G_ask_in_mapset( )	70
prompt for	existing database file	G_ask_old( )	69
prompt for an	existing group	I_ask_group_old( )	138
prompt for	existing site list file	G_ask_sites_in_mapset( )	106
prompt for	existing site list file	G_ask_sites_old( )	106
open an	existing site list file	G_fopen_sites_old( )	107
prompt for an	existing vector file	G_ask_vector_in_mapset( )	101
prompt for an	existing vector file	G_ask_vector_old( )	101
open an	existing vector file	G_fopen_vector_old( )	103
print error message and	exit	G_fatal_error( )	64
get text	extents	R_get_text_box( )	156
rewind vector	file	dig_rewind( )	125
prompt for existing cell	file	G_ask_cell_in_mapset( )	81
prompt for new cell	file	G_ask_cell_new( )	81
prompt for existing cell	file	G_ask_cell_old( )	81
prompt for existing database	file	G_ask_in_mapset( )	70
prompt for new database	file	G_ask_new( )	69
prompt for existing database	file	G_ask_old( )	69
prompt for existing site list	file	G_ask_sites_in_mapset( )	106
prompt for new site list	file	G_ask_sites_new( )	106
prompt for existing site list	file	G_ask_sites_old( )	106
prompt for an existing vector	file	G_ask_vector_in_mapset( )	101
prompt for a new vector	file	G_ask_vector_new( )	101
prompt for an existing vector	file	G_ask_vector_old( )	101
close a cell	file	G_close_cell( )	89
find a cell	file	G_find_cell2( )	82
find a cell	file	G_find_cell( )	82
find a database	file	G_find_file2( )	71
find a database	file	G_find_file( )	71
find a vector	file	G_find_vector2( )	102
find a vector	file	G_find_vector( )	102
open a new database	file	G_fopen_new( )	74
open a new site list	file	G_fopen_sites_new( )	107
open an existing site list	file	G_fopen_sites_old( )	107
open a new vector	file	G_fopen_vector_new( )	104
open an existing vector	file	G_fopen_vector_old( )	103
read a cell	file	G_get_map_row( )	87
read site list	file	G_get_site( )	107

reclass	file?	G_is_reclass( )	91
open an existing cell	file	G_open_cell_old( )	83
open a new database	file	G_open_new( )	74
write site list	file	G_put_site( )	108
read cell category	file	G_read_cats( )	91
read cell history	file	G_read_history( )	98
read vector category	file	G_read_vector_cats( )	105
remove a database	file	G_remove( )	75
rename a database	file	G_rename( )	75
unopen a cell	file	G_unopen_cell( )	89
write cell category	file	G_write_cats( )	92
write cell history	file	G_write_history( )	99
write vector category	file	G_write_vector_cats( )	105
read group REF	file	I_get_group_ref( )	140
read subgroup REF	file	I_get_subgroup_ref( )	140
write group REF	file	I_put_group_ref( )	140
write subgroup REF	file	I_put_subgroup_ref( )	140
format a segment	file	segment_format( )	180
get value from segment	file	segment_get( )	181
read row from segment	file	segment_get_row( )	182
put value to segment	file	segment_put( )	182
write row to segment	file	segment_put_row( )	181
get	file descriptor	rowio_fileno( )	176
open a database	file for reading	G_fopen_old( )	73
open a database	file for reading	G_open_old( )	72
open a database	file for update	G_fopen_append( )	73
open a database	file for update	G_open_update( )	73
retrieve cell	file name	D_get_cell_name( )	162
prompt for any valid	file name	G_ask_any( )	70
returns a temporary	file name	G_tempfile( )	108
add cell	file name to display list	D_set_cell_name( )	162
add	file name to Ref structure	I_add_file_to_group_ref( )	141
check for legal database	file names	G_legal_filename( )	72
open a new cell	file (random)	G_open_cell_new_random( )	85
write a cell	file (random)	G_put_map_row_random( )	88
open a new cell	file (sequential)	G_open_cell_new( )	84
write a cell	file (sequential)	G_put_map_row( )	88
open a new cell	file (uncompressed)	G_open_cell_new_uncompressed( )	85
read a cell	file (without masking)	G_get_map_row_nomask( )	87
	fill a box	R_box_abs( )	151
	fill a box	R_box_rel( )	151
	find a cell file	G_find_cell2( )	82
	find a cell file	G_find_cell( )	82
	find a database file	G_find_file2( )	71
	find a database file	G_find_file( )	71
	find a vector file	G_find_vector2( )	102
	find a vector file	G_find_vector( )	102
	find arc with point	dig_point_to_line( )	132
	find area with point	dig_point_to_area( )	132
select	fixed color table	R_color_table_fixed( )	149
select	floating color table	R_color_table_float( )	149
	flush graphics	R_flush( )	152
	flush pending updates to disk	segment_flush( )	182
choose	font	R_font( )	155

	force pending updates to disk	rowio_flush( )	176
	forget a row	rowio_forget( )	175
	format a segment file	segment_format( )	180
	free allocated memory	rowio_release( )	176
	free allocated memory	segment_release( )	183
	free category structure memory	G_free_cats( )	94
	free color structure memory	G_free_colors( )	96
	free Ref structure	I_free_group_ref( )	142
initialize	gis library	G_gisinit( )	64
	give current time to window	D_timestamp( )	161
prepare for raster	graphics	D_cell_draw_setup( )	165
terminate	graphics	R_close_driver( )	148
flush	graphics	R_flush( )	152
initialize	graphics	R_open_driver( )	148
initialize	graphics	R_set_RGB_color( )	154
identify current	graphics window	D_get_cur_wind( )	160
create new	graphics window	D_new_window( )	160
set current	graphics window	D_set_cur_wind( )	160
query	GRASS environment variable	G__getenv( )	67
query	GRASS environment variable	G_getenv( )	67
set	GRASS environment variable	G__setenv( )	67
set	GRASS environment variable	G_setenv( )	67
make linear	grey scale	G_make_grey_scale( )	97
prompt for new	group	I_ask_group_new( )	138
prompt for an existing	group	I_ask_group_old( )	138
read	group control points	I_get_control_points( )	143
write	group control points	I_put_control_points( )	144
does	group exist?	I_find_group( )	139
prompt for any valid	group name	I_ask_group_any( )	139
read	group REF file	I_get_group_ref( )	140
write	group REF file	I_put_group_ref( )	140
change error	handling	G_set_error_routine( )	65
reset normal error	handling	G_unset_error_routine( )	65
read vector	header	dig_read_head_binary( )	134
write vector	header	dig_write_head_binary( )	134
read the cell	header	G_get_cellhd( )	90
write the cell	header	G_put_cellhd( )	90
display vector	header information	dig_print_header( )	125
read cell	history file	G_read_history( )	98
write cell	history file	G_write_history( )	99
initialize	history structure	G_short_history( )	99
get	Hit RETURN msg	G_get_ask_return_msg( )	70
set	Hit RETURN msg	G_set_ask_return_msg( )	70
user's	home directory	G_home( )	117
	identify current graphics window	D_get_cur_wind( )	160
display vector header	information	dig_print_header( )	125
read target	information	I_get_target( )	142
write target	information	I_put_target( )	142
clears	information about current window	D_clear_window( )	161
	initialize category structure	G_init_cats( )	93
	initialize color structure	G_init_colors( )	96
	initialize conversions	D_do_conversions( )	162
	initialize gis library	G_gisinit( )	64
	initialize graphics	R_open_driver( )	148

get mouse	location using a line	R_get_location_with_line( )	156
get mouse	location using pointer	R_get_location_with_pointer( )	156
create a	lock	lock_file( )	169
remove a	lock	unlock_file( )	170
convert string to	lower case	G_tolcase( )	114
temporary close vector	map	dig_P_tmp_close( )	128
reopen closed vector	map	dig_P_tmp_open( )	128
read	map layer color table	G_read_colors( )	94
write	map layer color table	G_write_colors( )	95
assign/retrieve current	map window	D_check_map_window( )	160
current	mapset name	G_mapset( )	66
read a cell file (without	masking)	G_get_map_row_nomask( )	87
free category structure	memory	G_free_cats( )	94
free color structure	memory	G_free_colors( )	96
copy string to allocated	memory	G_store( )	114
free allocated	memory	rowio_release( )	176
free allocated	memory	segment_release( )	183
	memory allocation	G_calloc( )	76
	memory allocation	G_malloc( )	76
	memory allocation	G_realloc( )	76
pop-up	menu	D_popup( )	166
command line usage	message	G_parse_command_usage( )	111
change ctrl-c	message	V_intrpt_msg( )	190
print warning	message and continue	G_warning( )	64
print error	message and exit	G_fatal_error( )	64
print percent complete	messages	G_percent( )	117
get	mouse location using a box	R_get_location_with_box( )	157
get	mouse location using a line	R_get_location_with_line( )	156
get	mouse location using pointer	R_get_location_with_pointer( )	156
	move current location	R_move_abs( )	150
	move current location	R_move_rel( )	151
get Hit RETURN	msg	G_get_ask_return_msg( )	70
set Hit RETURN	msg	G_set_ask_return_msg( )	70
define	multiple colors	R_reset_colors( )	149
retrieve cell file	name	D_get_cell_name( )	162
prompt for any valid file	name	G_ask_any( )	70
current location	name	G_location( )	66
current mapset	name	G_mapset( )	66
return program	name	G_program_name( )	118
returns a temporary file	name	G_tempfile( )	108
user's	name	G_whoami( )	118
prompt for any valid group	name	I_ask_group_any( )	139
add cell file	name to display list	D_set_cell_name( )	162
color	name to number	D_translate_color( )	167
add file	name to Ref structure	I_add_file_to_group_ref( )	141
check for legal database file	names	G_legal_filename( )	72
read	next arc	dig_P_read_next_line( )	131
get	next arc	dig_read_next_line( )	126
get	next arc by type	dig_read_next_line_type( )	126
rewind	next-arc pointer	dig_P_rewind( )	131
reset	normal error handling	G_unset_error_routine( )	65
earth to array	(north)	D_u_to_a_row( )	163
earth to screen	(north)	D_u_to_d_row( )	163
color name to	number	D_translate_color( )	167

- 272 -

open a database file for	update	G_open_update()	73
	update range structure	G_row_update_range()	100
	update range structure	G_update_range()	100
force pending	updates to disk	rowio_flush()	176
flush pending	updates to disk	segment_flush()	182
convert string to	upper case	G_toucase()	114
command line	usage message	G_parse_command_usage()	111
interact with the	user	V_call()	189
	user's home directory	G_home()	117
	user's name	G_whoami()	118
get mouse location	using a box	R_get_location_with_box()	157
get mouse location	using a line	R_get_location_with_line()	156
get mouse location	using pointer	R_get_location_with_pointer()	156
prompt for any	valid file name	G_ask_any()	70
prompt for any	valid group name	I_ask_group_any()	139
get	value from segment file	segment_get()	181
put	value to segment file	segment_put()	182
query GRASS environment	variable	G__getenv()	67
query GRASS environment	variable	G_getenv()	67
set GRASS environment	variable	G__setenv()	67
set GRASS environment	variable	G_setenv()	67
end level one	vector access	dig_fini()	125
initialize level one	vector access	dig_init()	125
end level two	vector access	dig_P_fini()	128
initialize level two	vector access	dig_P_init()	128
read	vector category file	G_read_vector_cats()	105
write	vector category file	G_write_vector_cats()	105
rewind	vector file	dig_rewind()	125
prompt for an existing	vector file	G_ask_vector_in_mapset()	101
prompt for a new	vector file	G_ask_vector_new()	101
prompt for an existing	vector file	G_ask_vector_old()	101
find a	vector file	G_find_vector2()	102
find a	vector file	G_find_vector()	102
open a new	vector file	G_fopen_vector_new()	104
open an existing	vector file	G_fopen_vector_old()	103
read	vector header	dig_read_head_binary()	134
write	vector header	dig_write_head_binary()	134
display	vector header information	dig_print_header()	125
temporary close	vector map	dig_P_tmp_close()	128
reopen closed	vector map	dig_P_tmp_open()	128
printable	version of control character	G_unctrl()	114
print	warning message and continue	G_warning()	64
suppress	warnings?	G_suppress_warnings()	65
make color	wave	G_make_color_wave()	97
remove unnecessary	white space	G_squeeze()	113
remove leading/training	white space	G_strip()	114
assign/retrieve current map	window	D_check_map_window()	160
clears information about current	window	D_clear_window()	161
clip coordinates to	window	D_clip()	166
erase current	window	D_erase_window()	161
identify current graphics	window	D_get_cur_wind()	160
create new graphics	window	D_new_window()	160
remove a	window	D_remove_window()	161
set current graphics	window	D_set_cur_wind()	160

Index

- 276 -