GRASS 4.1 PROGRAMS

ABSTRACT

This document lists the currently running programs associated with version 4.1 of the Geographic Resources Analysis Support System (GRASS), developed at the US Army Construction Engineering Research Laboratories (USACERL) in Champaign, Illinois.

GRASS is a public-domain image-processing and geographic information system (GIS), written in the C programming language and running under the UNIX operating system. It was originally designed and developed by researchers in USACERL's Environmental Division to assist land managers at military installations. GRASS is now used by a wide variety of public and private agencies, including the Soil Conservation Service, National Park Service, U.S. Geological Survey, and many others. Some GRASS programs are contributed by these agencies and other users. The system continues to be developed at USACERL.

GRASS version 4.1 main and alpha commands (and most garden and contributed commands), adhere to the following naming conventions:

Prefix:

d.	- Display commands
g.	- General file management commands
i.	- Imagery commands
m.	- Data Import/Processing commands
p.	- Paint/Print commands
ps.	- PostScript program commands
r.	- Raster data commands
s.	- Sites data commands
v.	- Vector data commands

Suffix:

.sh	- Shell scripts (macros)

This naming scheme indicates the data type (raster, vector, sites) on which a command operates, the general functional area (display, imagery, data import/processing, general purpose) in which a command falls, or whether a command is a UNIX shell script macro.

In this document, commands are listed under their respective functional areas described here as follows:

1 - General File Management
2 - Window Management
3 - Extracting Data from Magnetic Tape
4 - Data Conversion: Importing and Exporting Data
5 - Interfaces Between GRASS and Other Software
6 - Digitizing and Map Development
7 - Image Processing
8 - Analyzing Data in GRASS
9 - Map Display
10 - Printing Maps
11 - Report Generation

NOTE: Commands in *italics* are new to or significantly enhanced in GRASS 4.1.

1. General File Management Commands

The following GRASS commands perform general management functions. They are designed to assist in the management of files and data and to provide access to various GRASS help features.

d.ask -	Prompts the user to select a GRASS database file from among files displayed in a menu on the graphics monitor.
exit -	Exits the user from the current GRASS session.
g.access -	Controls user access to the current GRASS mapset.
g.ask -	Prompts the user for the names of GRASS database files.
g.copy -	Copies available data files in the user's current mapset search path and location, to the appropriate element directories under the user's current mapset.
g.filename -	Prints GRASS database file names.
g.findfile -	Searches for GRASS database files and sets variables for the shell.
g.gisenv -	Outputs the user's current GRASS variable settings.
g.help -	GRASS help utility.
g.list -	Lists available GRASS database files of the specified data type to standard output.
g.manual -	Accesses GRASS Reference Manual entries.
g.mapsets -	Modifies the user's current mapset search path, affecting the user's access to data existing under the other GRASS mapsets in the current location.
g.region -	Program to manage the boundary definitions for the geographic region. A 3dview parameter is available when in non-interactive mode.
g.remove -	Removes database element files from the user's current mapset.
g.rename -	To rename database element files in the user's current mapset.
g.setproj -	Allows the user to create the PROJ_INFO and the PROJ_UNITS files to record the projection information associated with a current location.
g.tempfile -	Designed for shell scripts that need to use large temporary files. Creates a temporary file and prints the file name.
g.version -	Outputs the GRASS version number and date.
r.compress -	Compresses and decompresses raster files.

2. Window Management

These commands deal with the management of the two types of windows available in GRASS: graphics display frames and geographic regions.

2.1. Management of Graphics Display Frames

After the user has started and selected a graphics monitor for output (using the d.mon command), the user can subdivide the monitor into different "frames," and display different GRASS outputs in each frame. For example, the GRASS macro *3d.view.sh* divides the monitor into nine frames to demonstrate the 3-d viewing function of GRASS.

The following commands are used to manage the frames in which graphics are displayed on the user's graphics display device (monitor). These commands affect only the display of graphics, and do not alter the user's data.

d.erase - Erases the active display frame on the graphics monitor.

d.frame - Manages display frames on the graphics monitor.

2.2. Defining/Management of the Geographic Region

The commands listed here can be used to modify the settings of the user's geographic region. The settings of this region define the geographic boundaries, map projection, coordinate system, and resolution of a data set. GRASS commands commonly ignore data falling outside of this region. For example, when raster analysis programs are run on map layers, only those map areas that fall inside the user's current geographic region will be analyzed and included in the resultant map layer.

d.zoom - Allows the user to change the current geographic region settings interactively, with a mouse.

d.rast.zoom - To interactively zoom in or zoom out of regions on a raster map displayed in the active frame on the graphics monitor.

g.region - Program to manage the boundary definitions for the geographic region. A 3dview parameter is available when in non-interactive mode.

g.setproj - Allows the user to create the PROJ_INFO and the PROJ_UNITS files to record the projection information associated with a current location.

r.mask - Establishes and removes the current working mask.

3. Extracting Data from Magnetic Tapes

Several GRASS commands exist to examine and extract specific types of data from magnetic tape. Some of these programs are listed.

3.1. Examining, Extracting and Rotating Elevation Tape Data

The U.S. Geological Survey (USGS) and the Defense Mapping Agency (DMA) distribute digital elevation data at several resolutions and in different tape formats. These data are referred to as digital elevation models (DEMs) and digital terrain elevation data (DTED). The GRASS programs listed here extract this data from half-inch magnetic tape, list tape contents, rotate the data, and "flip" the data. USACERL distributes brief papers that distinguish elevation data types and detail the sequence of GRASS commands relevant to each.

m.examine.tape - Provides a description of the files on a half-inch magnetic tape.

m.dem.examine - Provides a terse description of USGS Digital Elevation Model (DEM) data files stored on half-inch magnetic tape.

m.dem.extract - Extracts USGS Digital Elevation Model (DEM) data from half-inch magnetic tape. Input may also come from a file.

m.dmaUSGSread - Extracts digital terrain elevation data (DTED) produced by the Defense Mapping Agency (DMA) but supplied by the USGS (in a different tape format) on half-inch magnetic tape.

m.dted.examine - Provides a terse description of levels 1 and 2 digital terrain elevation data (DTED) files produced and distributed by the Defense Mapping Agency (DMA) on half-inch magnetic tapes.

m.dted.extract - Extracts digital terrain elevation data (DTED - levels 1 and 2) produced and supplied by the Defense Mapping Agency (DMA) on half-inch magnetic tapes.

m.flip - Flips the orientation of map data.

m.rot90 - Rotates elevation data extracted by either m.dted.extract or m.dmaUSGSread.

3.2. Extracting Imagery Data

Several GRASS commands are also available to extract specific forms of satellite imagery data from magnetic tape. The following commands extract LANDSAT multi-spectral scanner (MSS), Thematic Mapper (TM), and other (e.g., SPOT) satellite data, as well as header information, from tape. The *GRASS Imagery Tutorial* distributed by USACERL discusses imagery data and details the logical sequence of GRASS commands relevant to these different data forms.

i.tape.mss - An imagery function that extracts Multispectral Scanner (MSS) imagery data from half-inch tape.

i.tape.mss.h - An imagery function that extracts header information from Landsat Multispectral Scanner (MSS) imagery data stored on half-inch tape.

i.tape.other - An imagery function that extracts scanned aerial imagery (NHAP, etc.) and SPOT imagery from half-inch magnetic tape.

i.tape.tm - An imagery function that extracts LANDSAT Thematic Mapper (TM) imagery from half-inch magnetic tape.

4. Data Conversion: Importing and Exporting Data

These commands are useful to those users importing and exporting data to and from GRASS. They perform ASCII/binary data conversions, raster, vector, and sites data format conversions, GRASS/other data format conversions, and map coordinate system and map projection conversions.

4.1. Moving Data to Another Computer - ASCII/Binary Conversions

These commands assist in ASCII/binary conversion of data. Specifically, commands with the .ascii extension bring data in from ASCII (to binary) and out to ASCII (from binary). Those with a .dlg extension bring data in from DLG-3 Optional format (to GRASS vector format) and out to DLG-3 Optional format (from GRASS vector format).

r.in.ascii - Converts an ASCII text file into a raster map layer.

r.out.ascii - Converts a raster map layer into an ASCII text file.

s.in.ascii - Converts a GRASS site_lists file in ASCII format to binary format.

s.out.ascii - Converts a GRASS site_lists file in binary format to ASCII format.

v.in.ascii - Converts ASCII vector map layers into binary vector map layers.

v.out.ascii - Converts binary vector map layers into ASCII vector map layers.

v.in.dlg - A new version of GRASS 4.0 v.in.dlg. (The GRASS 4.0 v.in.dlg has been renamed v.in.dlg2.) Capable of storing multiple attribute data from a USGS DLG file in a related text file that links back to a vector file in GRASS.

v.in.dlg2 - Converts binary DLG (BDLG) file to binary vector (dig) file.

v.out.dlg - Converts binary GRASS vector data to binary DLG-3 Optional format.

v.import - Converts ASCII Digital Line Graph (DLG) files, binary DLG files, and ASCII vector files into binary vector files and creates the needed vector support files.

4.2. Raster/Vector/Sites Conversions

These commands convert data among GRASS raster, vector, and sites formats.

i.quantize - An interactive imagery function that creates a raster map layer whose color table is based on the red, green, and blue color values present in existing, user-specified imagery group files.

r.contour - Produces a binary vector map of specified contours from a raster map layer.

r.digit - Interactive tool used to draw vector features on a graphics monitor using a pointing device (mouse), and save these features in a raster file.

r.line - Creates a new GRASS vector (dig) file by extracting linear features from a thinned raster file.

r.poly - Extracts area edges from a raster map layer and converts data to vector format.

r.thin - Thins non-zero cells that denote linear features in a raster file.

r.in.sunrast - Converts a SUN raster file to a GRASS raster file.

r.in.ll - Creates a raster file from data in latitude/longitude coordinates.

s.in.ascii - Converts a GRASS site_lists file in ASCII format to binary format.

s.out.ascii - Converts a GRASS site_lists file in binary format to ASCII format.

s.surf.tps - Interpolation and topographic analysis from given site data to GRASS raster format using spline with tension.

v.to.rast - Converts a map layer in (binary) GRASS vector format to GRASS raster format.

v.to.sites - Converts a GRASS vector file to a GRASS site_lists file.

4.3. GRASS to/from Other File Format Conversions

These commands convert GRASS files to/from other file formats such as ARC-INFO, DLG-3 Optional, DXF, and MOSS.

i.in.erdas - Creates GRASS raster map files from ERDAS files.

m.in.pl94.db3 - This program reads the Census PL94 data records from a file for one state. The file is usually on a CD-ROM, but this is not necessary if the proper path is given for the in=parameter and the contents of the file duplicate that on CD-ROM.

m.in.stf1.db3 - This program reads and assembles the Census STF1A data records from a set of 10 files for one state. The files are usually on a CD-ROM, but this is not necessary if the proper path is given for the in=parameter and all ten files are in the same directory with their normal names.

m.in.stf1.tape - This is a text filter program written in C especially to work with the Census STF1 files, but is useful for selecting subsets of lines from any text file. It will work with arbitrarily long input lines, up to 10000 characters. Input lines may be of variable length.

v.apply.census - Calculate/import demographics from Census STF1 files.

v.in.arc - Converts data in ARC/INFO format to GRASS's vector format, and stores output in the user's current GRASS mapset.

v.out.arc - Converts GRASS vector files to ARC/INFO's "Generate" file format.

v.in.dlg - A new version of GRASS 4.0 v.in.dlg. (The GRASS 4.0 v.in.dlg has been renamed v.in.dlg2.) Capable of storing multiple attribute data from a USGS DLG file in a related text file that links back to a vector file in GRASS.

v.in.dlg2 - Converts binary DLG (BDLG) file to binary vector (dig) file.

v.out.dlg - Converts binary GRASS vector data to binary DLG-3 Optional format.

v.in.dxf - DXF format to GRASS vector format conversion program.

v.out.dxf - GRASS vector format to DXF format conversion program.

v.in.tig.basic - Creates GRASS vector maps from TIGER files.

v.in.tig.lndmk - Creates GRASS vector maps from TIGER files.

v.in.tig.rim - Imports and converts line data in Census Bureau TIGER format to GRASS's vector format, and stores output in the user's current GRASS mapset.

v.out.moss - Converts GRASS site, line, or area data into MOSS import format.

r.in.sunrast - Converts a SUN raster file to a GRASS raster file.

m.lulc.USGS - Creates raster map layers from a Composite Theme Grid (CTG) file created by m.lulc.read. m.lulc.read extracts the CTG data from an ASCII landuse/landcover (lulc) CTG format file supplied by the USGS.

tig.rim.sh - Generates two vector map layers from a RIM/TIGER database.

4.4. Coordinate Conversions and Map Projections

The user can also perform map coordinate conversions and map projection transformations, using the following GRASS commands.

m.datum.shift - Datum shift program.

m.gc2ll - Converts geocentric coordinates to geographic coordinates.

m.ll2gc - Converts geographic coordinates to geocentric coordinates.

m.ll2u - Converts geographic (latitude/longitude) coordinates to Universal Transverse Mercator (UTM) coordinates.

m.u2ll - Converts Universal Transverse Mercator (UTM) coordinates to geographic (latitude/longitude) coordinates.

m.lulc.read - Extracts Landuse/Landcover data in the ASCII Composite Theme Grid (CTG) data format distributed by the USGS into a working file for m.lulc.USGS.

m.lulc.USGS - Creates raster map layers from a Composite Theme Grid (CTG) file created by m.lulc.read. m.lulc.read extracts the CTG data from an ASCII landuse/landcover (lulc) CTG format file supplied by the USGS.

m.proj - Calculates conversion coordinates for geographic positions.

m.region.ll - Converts Universal Transverse Mercator (UTM) coordinates falling within the current geographic region from UTM coordinates to geographic (latitude/longitude) coordinates.

m.tiger.region - Program to extract the boundaries of a geographic region sufficient to encompass all data in a user-specified TIGER file. Program also works with type 4 files.

r.mapcalc - Raster map layer data calculator.

r.in.ll - Creates a raster file from data in latitude/longitude coordinates.

v.proj - Allows projection conversion of vector files.

v.transform - Transforms an ASCII vector map layer from one coordinate system into another coordinate system.

Satellite imagery data are generally made available in an x,y coordinate system. To analyze imagery data in combination with other GRASS data layers, it is necessary that all these data be rectified to the same map coordinate system and projection. Several GRASS programs are used to rectify imagery data.

i.ortho.photo - An interactive imagery function for the ortho-rectification of imagery group files.

i.points - An imagery function that enables the user to mark coordinate system points on an image to be rectified and then input the coordinates of each point for creation of a coordinate transformation matrix. The transformation matrix is needed as input for the GRASS program i.rectify.

i.rectify - An imagery function that rectifies an image by computing a coordinate transformation for each cell (pixel) in the image using the transformation coefficient matrix created by the GRASS program i.points.

i.rectify2 - An imagery function that rectifies an image by computing a coordinate transformation for each pixel in the image, based on the control points created by the GRASS program i.vpoints. Provides second and third order polynomial rectification.

5. Interfaces Between GRASS and Other Software

One function usefully performed by GRASS is to output data in a form suitable for input to other existing computer models. GRASS programs allow GRASS data to be interfaced with those of X-Windows (X-Windows user interface), MAPGEN (map generation functions for plotter output), PPM (portable pixmap utilities), ELAS (image processing), UW-RIM (University of Washington's version of the RIM relational database management system), the "S" statistical package, and ISM (interactive surface modeling) programs. The user can, of course, use GRASS programs to put data into a form suitable for import and export to/from programs other than these.

6. Digitizing and Map Development

To be used by GRASS programs, data must be digitally stored in a GRASS database. Data can be entered into a GRASS database in one of several ways: (1) hardcopy data (like paper maps) may be either digitized or scanned into GRASS's vector file format; (2) data already available in another digital format (like ARC-INFO data) may be converted into GRASS's digital data file format, and stored in a GRASS database; (3) GRASS analysis programs can be used to create new GRASS data from data already stored in GRASS digital data file format. The following GRASS programs are designed for the input, manipulation, and adjustment of data from sources outside of GRASS.

6.1. Digitizing Maps

These commands allow for the addition of paper (and other hardcopy) geographic information into GRASS databases, and for the manipulation of vector data in GRASS.

r.digit - Interactive tool used to draw vector features on a graphics monitor using a pointing device (mouse), and save these features in a raster file

r.patch - Creates a composite raster map layer by using known category values from one (or more) map layer(s) to fill in areas of "no data" in another map layer.

r.random - Creates a raster map layer and sites list containing randomly located sites.

s.menu - Accesses and manipulates GRASS sites data.

v.digit - A new version of GRASS 4.0 v.digit. (The GRASS 4.0 v.digit has been renamed v.digit2.) Upgraded so that it no longer requires drivers to be written for each digitizer supported.

v.digit2 - A menu-driven, highly interactive map development program used for vector digitizing, editing, labeling and converting vector data to raster format.

v.mkgrid - Creates a (binary) GRASS vector map of a user-defined grid.

v.mkquads - Creates a GRASS vector map layer and/or sites list and/or geographic region definition file for a USGS 7.5-minute quadrangle.

v.patch - Creates a new binary vector map layer by combining other binary vector map layers.

v.proj - Allows projection conversion of vector files.

v.support - Creates GRASS support files for (binary) GRASS vector data.

v.to.rast - Converts a map layer in (binary) GRASS vector format to GRASS raster format.

v.to.sites - Converts a GRASS vector file to a GRASS site_lists file. Supports s.surf.tps.

6.2. Editing and Patching Map Data

Frequently, (due to the size of digitizing tablets) users digitize data in relatively small chunks which must be "patched" together before data are analyzed. These GRASS commands are used to edit and patch digital data.

d.rast.edit - Program allowing users to interactively edit the cell category values of raster map layers displayed on the graphics monitor.

r.mapcalc - Raster map layer data calculator.

r.patch - Creates a composite raster map layer by using known category values from one (or more) map layer(s) to fill in areas of "no data" in another map layer.

v.clean - Program will go through a vector file and clean out all dead lines, potentially reducing the size of the file.

v.cutter - This program provides a way to generate new maps based on an intersection of two existing maps. It, in effect, provides a way to create masked versions of vector maps. Lines, sites, and polygons are clipped correctly.

v.patch - Creates a new binary vector map layer by combining other binary vector map layers.

v.prune - Prunes points from binary GRASS vector data files.

v.spag - Processes a Spaghetti-digitized vector file. Program now stable enough to reside in main GRASS code. New parameter added for use in command line: -i, which removes existing identical lines.

v.trim - Trims small spurs, and removes excessive nodes from a binary GRASS vector (dig) file.

6.3. Creating Support Files for GRASS Maps

A variety of supporting information is needed for each GRASS "map layer." For data stored in GRASS vector format, information on the location of vectors, the file topology, vector category values, and category labels are stored in separate files. For data stored in GRASS raster format, additional files are also stored to hold information on category colors, the map's development history, etc. The following programs help the user build necessary GRASS support files for raster and vector data.

r.support - Allows the user to create and/or modify raster map layer support files.

v.alabel - Bulk labels unlabeled area features in a binary GRASS vector file.

v.support - Creates GRASS support files for (binary) GRASS vector data.

6.4. Importing and Exporting Data Between Other Data Formats

Often, data which one wishes to use in a GRASS database are already available in digital data formats other than GRASS. Similarly, users may wish to export data from GRASS into other software systems' data formats. A number of GRASS programs are available to import and export data to and from GRASS.

i.in.erdas - Creates raster map files from ERDAS files.

r.in.ascii - Converts an ASCII text file into a raster map layer.

r.in.ll - Creates a raster file from data in latitude/longitude coordinates.

r.in.poly - Allows creation of raster maps from an ASCII polygon/line data file.

r.out.ascii - Converts a raster map layer into an ASCII text file.

v.import - Converts ASCII Digital Line Graph (DLG) files, binary DLG files, and ASCII vector files into binary vector files and creates the needed vector support files.

v.in.dxf - DXF format to GRASS vector format conversion program.

v.in.transects - Imports transect data to a GRASS vector map. A transect is a line or an area, and a length (in meters or feet).

v.out.dxf - GRASS vector format to DXF format conversion program.

v.support - Creates GRASS support files for (binary) GRASS vector data.

7. Image Processing

Remotely sensed images, such as satellite data and aerial photographs, are widely available in a digital format. The data in these images can be interpreted using image processing techniques that classify image elements based on the spectral reflectance values of individual image pixels or on user-identified pixel groupings. GRASS integrates GIS with image processing capabilities. This allows image data to augment a GRASS database, and allows image classifications to be guided by known elements in other maps in the GIS database. Processing of remotely sensed imagery typically involves: (1) extracting data from their magnetic storage media, (2) entering extracted data into a GRASS database, (3) classifying pixels and elements in the image, (4) rectifying the image to a map coordinate system and projection, and (5) correcting and enhancing the image.

GRASS commands commonly used to perform image processing are listed. Because imagery is stored as raster data, the GRASS raster analysis functions can be used to analyze imagery. The paper *r.mapcalc: An Algebra for GIS and Image Processing* describes ways in which r.mapcalc can be used as an image processing tool.

7.1. Tape Extraction

Once imagery data are obtained from agencies, they must be extracted from the magnetic tapes on which they are stored. GRASS commands exist to extract LANDSAT Thematic Mapper (TM), Multi-Spectral Scanner (MSS), and such other satellite imagery as SPOT data from half-inch magnetic tape. Procedures for extracting this data from tape and importing it into a GRASS database are described in the *GRASS Imagery Tutorial*.

i.tape.mss - An imagery function that extracts Multispectral Scanner (MSS) imagery data from half-inch tape.

i.tape.mss.h - An imagery function that extracts header information from Landsat Multispectral Scanner (MSS) imagery data stored on half-inch tape.

i.tape.other - An imagery function that extracts scanned aerial imagery (NHAP, etc.) and SPOT imagery from half-inch magnetic tape.

i.tape.spot - Program extracts SPOT imagery from 9-track, half-inch tape.

i.tape.tm - An imagery function that extracts LANDSAT Thematic Mapper (TM) imagery from half-inch magnetic tape.

i.tape.tm.fast - An imagery function that extracts Thematic Mapper (TM) imagery from tape media.

7.2. File Management

Users can "group" imagery files for analysis purposes, and "target" imagery files to the files in another GRASS location. These are basic commands for the management of imagery files.

i.group - An imagery function that creates and edits groups and subgroups of (raster) imagery files.

i.target - An imagery function that establishes a GRASS target LOCATION for an imagery group.

7.3. Image Classification

Image classification is the process of categorizing the data in a raster image based on the spectral reflectance values of each map pixel (cell). Classification can be done using unsupervised or supervised methods. GRASS contains functions to conduct both kinds of classifications. In a supervised classification, the user can define the categories into which pixels are to be placed; in an unsupervised classification, the computer attempts to categorize pixels in a user-defined number of attempts based on statistical regularities in the data.

i.cca -	Canonical components analysis (cca) program for image processing.
i.class -	An imagery function that generates spectral signatures for an image by allowing the user to outline regions of interest. The resulting signature file can be used as input for i.maxlik or as a seed signature file for i.cluster.
i.cluster -	An imagery function that generates spectral signatures for land cover types in an image using a clustering algorithm. The resulting signature file is used as input for i.maxlik. The program can be run interactively or non-interactively.
i.gensig -	A non-interactive method for generating input into i.maxlik.
i.gensigset -	A non-interactive method for generating input into i.smap.
i.maxlik -	An imagery function that classifies the cell spectral reflectances in imagery databased on the spectral signature information generated in i.cluster.
i.pca -	Principal components analysis (pca) program for image processing.
i.smap -	An imagery function that performs contextual image classification using sequential maximum a posteriori (SMAP) estimation and multimodal signatures (generated by i.gensigset).
i.zc -	Zero-crossing "edge detection" raster function for image processing.
r.mapcalc -	Raster map layer data calculator.

7.4. Geometric Rectification

Imagery data are generally made available in an x,y coordinate system. To analyze imagery data in combination with other GRASS data layers, it is necessary that all these data be rectified to the same coordinate system and map projection. Several GRASS programs are used to rectify imagery data.

i.points -	An imagery function that enables the user to mark coordinate system points on an image to be rectified and then input the coordinates of each point for creation of a coordinate transformation matrix. The transformation matrix is needed as input for the GRASS program i.rectify.
i.rectify -	An imagery function that rectifies an image by computing a coordinate transformation for each cell (pixel) in the image using the transformation coefficient matrix created by the GRASS program i.points.
i.rectify2 -	This imagery function rectifies an image by computing a coordinate transformation for each pixel in the image, based on the control points created by the GRASS program i.vpoints. Provides second and third order polynomial rectification.
i.ortho.photo -	An interactive imagery function for the ortho-rectification of imagery group files.
i.vpoints -	Identifies coordinate pairs of points from a vector map or keyboard entry and corresponding points in an image. Works with i.rectify and i.rectify2.

7.5. Image Correction

Commonly, when analyzing multiple images, it is necessary to correct image distortions attributable to such sources as the earth's radiation. Such distortions can result in different spectral reflectance values being collected for the same image pixel, based on the time of day, month, year, etc., at which the image was photographed. GRASS programs exist which help the user to identify and eliminate such distortions from images, allowing valid comparisons to made among images. See the paper *r.mapcalc: An Algebra for*

GIS and Image Processing for an example of how radiometric corrections can be made to an image.

i.fft - Fast Fourier Transform (FFT) for image processing.

i.ifft - Inverse Fast Fourier Transform (ifft) for image processing.

r.mapcalc - Raster map layer data calculator.

7.6. Image Enhancement

GRASS programs can be used to enhance or subdue certain data values to make more evident certain features or qualities of digital imagery.

i.colors - An imagery function that creates colors for imagery groups.

i.composite - An imagery function that creates a color composite image from three-band files specified by the user.

i.grey.scale - An imagery function that assigns a histogram contrast stretch grey scale color table to a raster map layer.

i.his.rgb - Hue-intensity-saturation (his) to red-green-blue (rgb) raster map color transformation function.

i.quantize - An interactive imagery function that creates a raster map layer whose color table is based on the red, green, and blue color values present in existing, user-specified imagery group files.

i.rgb.his - Red-green-blue (rgb) to hue-intensity-saturation (his) function for image processing.

r.mapcalc - Raster map layer data calculator.

7.7. Building Custom Filters

The user may wish to model interactions across a landscape, or to remove systematic distortions occurring across a map or image. Both applications can be approached by filtering data. The user can build custom filters to make the value of one pixel a (user-defined) function of the values in the surrounding cells. The paper *r.mapcalc: An Algebra for GIS and Image Processing* provides examples of how some spatial filters commonly used in image processing can be built using *r.mapcalc*. See also the section 8.6, "Analyzing Data in GRASS: Neighborhood Analysis/Filters."

i.zc - Zero-crossing "edge detection" raster function for image processing.

r.mapcalc - Raster map layer data calculator.

r.mfilter - Raster file matrix filter.

r.neighbors - Makes each cell category value a function of the category values assigned to the cells around it, and stores new cell values in an output raster map layer.

8. Analyzing Data in GRASS

GRASS was designed as an image processing and map analysis system. Most GRASS analysis programs operate on raster data; s.db.rim operates on site data. GRASS programs exist that allow the user to convert GRASS data between raster, vector, and site formats. GRASS data analysis functions can be employed for such tasks as: (1) general data manipulation, (2) site data analysis, (3) two- and three-dimensional manipulations, (4) single-cell map reporting functions, (5) multi-cell coincidence tabulations and comparisons, (6) neighborhood analysis and filtering, (7) regional analysis and filtering, (8) proximity analysis, (9) Boolean overlay functions, and (10) terrain analysis functions.

8.1. General Data Manipulation and Analysis Tools

The programs listed here are used for general data manipulation and analysis. Several of these programs are also cross-listed under other categories.

m.in.pl94.db3 - This program is provided to read the Census PL94 data records from a file for one state. The file is usually on a CD-ROM, but this is not necessary if the proper path is given for the in=parameter and the contents of the file duplicate that on CD-ROM.

m.in.stf1.db3 - This program is provided to read and assemble the Census STF1A data records from a set of ten files for one state. The files are usually on a CD-ROM, but this is not necessary if the proper path is given for the in=parameter and all ten files are in the same directory with their normal names.

m.in.stf1.tape - This is a text filter program written in C especially to work with the Census STF1 files, but useful for selecting subsets of lines from any text file. It will work with arbitrarily long input lines, up to 10000 characters. Input lines may be of variable length.

r.binfer - Bayesian expert system development function.

r.colors - Creates/modifies the color table associated with a raster map layer.

r.combine - Allows category values from several raster map layers to be combined.

r.contour - Produces a binary vector map of specified contours from a raster map layer.

r.grow - Generates an output raster map layer with contiguous areas grown by one cell (pixel).

r.infer - Outputs a raster map layer whose category values represent the application of user-specified criteria (rules statements) to other raster map layers' category values.

r.mapcalc - Raster map layer data calculator.

r.mask - Establishes and removes the current working mask.

r.mask.points - Examines and filters lists of points constituting lines to determine if they fall within the current region and mask and optionally an additional raster map.

r.median - Finds the median of values in a cover raster map layer within areas assigned the same category value in a user-specified base raster map.

r.mode - Finds the mode of values in a cover map within areas assigned the same category value in a user-specified base map.

r.reclass - Creates a new map layer whose category values are based upon the user's reclassification of categories in an existing raster map layer.

r.resample - GRASS raster map layer data resampling capability.

r.rescale - Rescales the range of category values in a raster map layer.

r.weight - Interactive raster map overlay function.

r.weight2 - Non-interactive version of r.weight.

v.area - Display GRASS area and perimeter information for a GRASS vector map.

v.reclass - Creates a new map layer whose category values are based upon the user's reclassification of categories in an existing vector map layer.

8.2. Site Data

Site data can be analyzed in GRASS either in their site format or after conversion to raster data format. The following GRASS programs are used to analyze site data.

s.menu - Accesses and manipulates GRASS sites data.

s.surf.idw - Surface generation program, from sites data.

s.surf.tps - Interpolation and topographic analysis from given site data to GRASS raster format using spline with tension.

8.3. 2-D and 3-D Manipulations

GRASS programs can be used to perform two- and three-dimensional data manipulations. These functions are useful for modeling iterative interactions across a landscape.

r.basins.fill - Generates a raster map layer showing watershed sub-basins.

r.contour - Produces a binary vector map of specified contours from a raster map layer.

r.drain - Traces a flow through an elevation model on a raster map layer.

r.surf.contour - Surface generation program.

r.surf.idw - Surface generation program, using raster data; works with latitude/longitude databases.

r.surf.idw2 - Surface generation program, using raster data; does not work with latitude/longitude databases.

r.watershed - Watershed basin analysis program.

s.surf.tps - Interpolation and topographic analysis from given site data to GRASS raster format using spline with tension.

8.4. Single Cell Map Reporting Functions

The functions listed report information about a single cell, in one or more raster map layers.

d.what.rast - Allows the user to interactively query the category contents of multiple raster map layers at user-specified locations within the current geographic region.

d.rast.arrow - Draws arrows representing cell aspect direction for a raster map layer.

d.rast.num - Overlays cell category values on a raster map layer displayed to the graphics monitor.

r.covar - Outputs a covariance/correlation matrix for a user-specified raster map layer.

r.describe - Prints a terse list of category values found in a raster map layer.

r.info - Outputs basic information about a user-specified raster map layer.

r.profile - Outputs the raster map layer values lying on user-defined lines.

r.report - Reports statistics for raster map layers.

r.stats - Generates area statistics for raster map layers.

r.transect - Outputs raster map layer values lying along user-defined transect lines.

r.what - Queries raster map layers about their category values and category labels.

r.volume - Sums cell values within clumps and calculates volumes and centroids of patches or clumps.

8.5. Multi-Cell Coincidence Tabulations and Comparisons

The following GRASS functions listed report back information about multiple cells in one or more map layers, in a way useful for making correlations between data.

d.what.rast - Allows the user to interactively query the category contents of multiple raster map layers at user-specified locations within the current geographic region.

r.coin - Tabulates the mutual occurrence (coincidence) of categories for two raster map layers.

r.report - Reports statistics for raster map layers.

r.stats - Generates area statistics for raster map layers.

r.what - Queries raster map layers about their category values and category labels.

8.6. Neighborhood Analysis/Filters

The user may wish to model interactions across a landscape, or to remove systematic distortions occurring across a map or image. The user may also wish to eliminate "noise" from map data to make the basic results more visually apparent. Such applications can be approached by filtering data. The user can build custom filters to make the value of one pixel a (user-defined) function of the values in the surrounding cells. The paper *r.mapcalc: An Algebra for GIS and Image Processing* provides examples of how some spatial filters commonly used in image processing can be built using r.mapcalc. See past issues of the newsletter *GRASSClippings* for other examples of custom filters for specific applications. See also the section 7.7, "Image Processing: Building Custom Filters."

d.rast.arrow - Draws arrows representing cell aspect direction for a raster map layer.

r.basins.fill - Generates a raster map layer showing watershed sub-basins.

r.buffer - Creates a raster map layer showing buffer zones surrounding cells that contain non-zero category values.

r.cost - Outputs a raster map layer showing the cumulative cost of moving between different geographic locations on an input raster map layer whose cell category values represent cost. Capable of rapid construction of hydrographs.

r.clump - Recategorizes data in a raster map layer by grouping cells that form physically discrete areas into unique categories.

r.drain - Traces a flow through an elevation model on a raster map layer.

r.grow - Generates an output raster map layer with contiguous areas grown by one cell (pixel).

r.mapcalc - Raster map layer data calculator.

r.median - Finds the median of values in a cover raster map layer within areas assigned the same category value in a user-specified base raster map.

r.mode - Finds the mode of values in a cover map within areas assigned the same category value in a user-specified base map.

r.neighbors - Makes each cell category value a function of the category values assigned to the cells around it, and stores new cell values in an output raster map layer.

r.slope.aspect - Generate raster map layers of slope and aspect from a raster map layer of true elevation values. Slope format may be specified.

r.thin - Thins non-zero cells that denote linear features in a raster file. Program enhanced through use of a new thinning algorithm.

r.watershed - Watershed basin analysis program.

8.7. Regional Analysis/Filters

GRASS can also be used to analyze and filter data "regions." Neighborhood filters modify each cell value as a function of the cell values found in its (square) neighborhood. Regional filters make each cell value a function of the values found within its (user-defined) region/clump of cells. A region can be defined as a contiguous group of cells having the same category value. Such filters are useful for imagery analysis and other applications.

i.zc - Zero-crossing "edge detection" raster function for image processing.

r.average - Finds the average of values in a values map within polygons of a user-specified base map.

r.clump - Recategorizes data in a raster map layer by grouping cells that form physically discrete areas into unique categories.

r.profile - Outputs the raster map layer values lying on user-defined lines.

r.transect - Outputs raster map layer values lying along user-defined transect lines.

r.volume - Sums cell values within clumps and calculates volumes and centroids of patches or clumps.

8.8. Proximity Analysis

GRASS can be used to examine the proximity of certain map categories from others. Often, this is useful when determining which geographic areas warrant further analysis. For example, if investigating potential nesting sites of species X, the user might restrict his analysis to areas within a 300-meter radius of cells containing relevant species habitat.

r.buffer - Creates a raster map layer showing buffer zones surrounding cells that contain non-zero category values.

8.9. Boolean Overlay Functions

GRASS can perform basic Boolean overlay functions, involving data union ("or" operations), intersection ("and" operations), and exclusion ("not" operations). The GRASS commands listed here are used to do this.

r.combine -	Allows category values from several raster map layers to be combined.
r.cross -	Creates a cross-product of the category values from multiple raster map layers.
r.infer -	Outputs a raster map layer whose category values represent the application of user-specified criteria (rules statements) to other raster map layers' category values.
r.mapcalc -	Raster map layer data calculator.

8.10. Terrain Analysis

Elevation data are crucial to any GIS. A number of GRASS commands were designed specifically to address terrain analysis issues related to water movement, development of ballistic trajectories, and computation of slope and aspect. Although the following GRASS commands listed here were designed to analyze terrain data, they in fact can be used to analyze any data types. See also d.3d, r.mapcalc, r.clump, and the paper *r.mapcalc: An Algebra for GIS and Image Processing*.

d.rast.arrow -	Draws arrows representing cell aspect direction for a raster map layer.
r.contour -	Produces a GRASS binary vector map of specified contours from a GRASS raster map layer.
r.cost -	Outputs a raster map layer showing the cumulative cost of moving between different geographic locations on an input raster map layer whose cell category values represent cost. Capable of rapid construction of hydrographs.
r.drain -	Traces a flow through an elevation model on a raster map layer.
r.los -	Line-of-sight raster analysis program.
r.slope.aspect -	Generate raster map layers of slope and aspect from a raster map layer of true elevation values.
r.volume -	Sums cell values within clumps and calculates volumes and centroids of patches or clumps.
r.watershed -	Watershed basin analysis program.
s.surf.tps -	Interpolation and topographic analysis from given site data to GRASS raster format using spline with tension.

9. Map Display

GRASS includes a full range of functions for display of GRASS outputs on the user's graphics device. These commands manage the graphics display device (monitor), manage the display frames to which output is sent, report on the contents of the images displayed to the monitor, and are used for map design, display, input and screen capture.

9.1. Management of Graphics Display Monitor

GRASS supports the use of multiple graphics display monitors during a GRASS session. The d.mon command is used to start, select, stop, and unlock graphics monitors for GRASS display output.

d.mon -	To establish and control use of a graphics display monitor.

9.2. Management of Display Frames on the Graphics Display Monitor

After the user has started and selected a graphics monitor for output, the user can subdivide the monitor into different frames, and display different GRASS outputs in each frame. For example, the GRASS program i.points divides the monitor into multiple frames to allow the user to target rectification points on an image to (user-known) points on another map layer. Similarly, the GRASS macro 3d.view.sh divides the monitor into nine frames to demonstrate the 3-d viewing function of GRASS.

d.erase - Erases the active display frame on the graphics monitor.

d.frame - Manages display frames on the graphics monitor.

9.3. Map Display Reporting Functions

Several GRASS commands enable the user to query the contents of raster map layers displayed in the active frame on the user's graphics monitor.

d.measure - Measures the lengths and areas of features drawn by the user in the active display frame on the graphics monitor. Works in both UTM and lat/lon coordinate systems.

d.rast.arrow - Draws arrows representing cell aspect direction for a raster map layer.

d.rast.num - Overlays cell category values on a raster map layer displayed to the graphics monitor.

d.what.rast - Allows the user to interactively query the category contents of multiple raster map layers at user-specified locations within the current geographic region.

d.what.vect - Allows the user to interactively query the category contents of multiple (binary) vector map layers at user-selected locations within the current geographic region.

d.where - Identifies the geographic coordinates associated with point locations in the active frame on the graphics monitor.

9.4. Map Design, Display, Input and Capture

Numerous GRASS commands enable the user to develop, display, and capture raster, vector, site, textual, and symbol/icon data to the graphics display monitor. Similar functions are available for hardcopy map design and output (see section 10, "Printing Maps").

grass.logo.sh - Displays a GRASS/Army Corps of Engineers logo in the active display frame, on the graphics monitor.

show.color.sh - Displays and names available primary colors used by GRASS programs, in frames on the graphics monitor.

show.fonts.sh - Displays and names available font types, in the active display frame on the graphics monitor.

slide.show.sh - Displays a series of raster map layers existing in the user's current mapset search path on the graphics monitor.

3d.view.sh - Displays nine three-dimensional views of the spearfish sample data set on the user's graphics monitor, demonstrating use of the program d.3d.

d.3d - Three-dimensional raster map display program.

d.colormode - Allows the user to establish whether a map will be displayed using its own color table or the fixed color table of the graphics monitor.

d.colors - Allows the user to interactively change the color table of a raster map layer displayed on the graphics monitor.

d.colortable - To display the color table associated with a raster map layer.

d.display - Interactive program to display textual, symbolic, raster, vector, and site data in the active frame on the user's graphics monitor.

d.font - Selects text fonts to be used for text display on the graphics monitor.

d.geodesic - Displays a geodesic line, tracing the shortest distance between two geographic points along a great circle, in a latitude/longitude data set.

d.graph - Program for generating and displaying simple graphics to the graphics display monitor.

d.grid - Overlays a user-specified grid in the active display frame on the graphics monitor.

d.his - Produces and displays a raster map layer combining hue, intensity, and saturation (his) values from user-specified input raster map layers.

d.histogram - Plots a histogram in the form of a pie or bar chart for a user-specified raster file.

d.icons - Displays points, as icons, at user-defined locations in the active display frame on the graphics monitor.

d.label - Creates and places text labels in the active display frame on the graphics monitor.

d.labels - To create/edit GRASS label files for display on the graphics monitor.

d.legend - Displays a legend for a raster map layer in the active frame on the graphics monitor.

d.mapgraph - Generates and displays simple graphics on raster map layers drawn in the active graphics monitor display frame.

d.menu - Creates and displays a menu within the active frame on the graphics monitor.

d.paint.labels - Displays text labels formatted for use with GRASS paint (p.map, p.labels) output to the active frame on the graphics monitor.

d.points - Displays point graphics in the active frame on the graphics display monitor.

d.profile - Displays profiles of a user-specified raster map layer in the active frame on the user's graphics monitor.

d.rgb - Allows multiple maps to be overlaid in the active display frame on the graphics monitor.

d.rhumbline - Displays the rhumbline joining two user-specified points in the active frame on the user's graphics monitor.

d.save - Creates a list of commands for recreating screen graphics.

d.scale - Displays a map scale and north arrow relevant to a the user's current geographic region setting in the active display frame on the graphics monitor.

d.sites - Displays site markers in the active display frame on the graphics monitor.

d.text - Draws text in the active display frame on the graphics monitor.

d.title - Outputs a title for a raster map layer in a form suitable for display by d.text.

d.vect - Displays GRASS vector data in the active frame on the graphics monitor.

10. Printing Maps

The map printing process parallels that for map display. Typically, however, printing of outputs is done only after all map analysis is complete. The user should design a map's contents, select a paint device (printer) to which output will be sent, and then print the map.

10.1. Designing Maps for Printed Output

A full range of map design functions, similar to those available for map display, are accessed through the GRASS commands listed here.

p.colors - Allows the user to modify a color table for a raster map layer, assigning colors to the categories in the raster map layer based on printer color numbers (instead of red, green, blue percentages).

p.icons - Allows the user to create and maintain icons which are used by the p.map command to depict sites.

p.labels - Creates and modifies labels for hardcopy maps.

p.map - Command language interface to color hardcopy and graphics monitor output.

p.map.new - Produces color maps for output on a color hardcopy device or a graphics monitor. Output can include a raster map, any number of vector overlays, site data, text labels, and other map elements.

ps.icon - Allows the user to create and maintain icons which are used by ps.map to depict sites.

ps.map - Produces an output file containing a PostScript program to produce hardcopy map products on system's PostScript output device. Output can include a raster map, any number of vector overlays, site data, text labels, and other spatial data.

10.2. Choosing a Printer for Hardcopy Output

A user may have several printers (and display devices) connected to a GRASS system. Before printing a map, the user must first select which device will be used to print output produced by the GRASS paint/print commands. In GRASS, the *p.select* command is used to select a device for paint/print output. The *GRASS Hardware Configuration Guide* lists painters/printers to which GRASS paint/print output can be sent. In addition to hardcopy output devices (printers), a "preview" driver also exists to send paint output to a user's graphics display monitor. User sites can also elect to write new device drivers. The *GRASS Programmer's Manual* and the *GRASS Installation Guide* discuss some of the requirements of device drivers.

p.select - Selects a device (printer) for GRASS hardcopy output. Outputs can also be previewed on the graphics display monitor.

ps.select - Allows the user to select the PostScript device for GRASS hardcopy output.

10.3. Printing Hardcopy Map Output

The following commands exist to print the output produced by GRASS *paint* commands.

p.chart - Prints a color chart for the printer currently selected by the user.

p.map - Command language interface to color hardcopy and graphics monitor output.

p.map.new - Produces color maps for output on a color hardcopy device or a graphics monitor. Output can include a raster map, any number of vector overlays, site data, text labels, and other map elements.

p.ppm - Reads portable pixmap (ppm) files created by PPM utilities.

ps.map - Produces an output file containing a PostScript program to produce hardcopy map products on system's PostScript output device. Output can include a raster map, any number of vector overlays, site data, text labels, and other spatial data.

11. Report Generation

Several commands exist in GRASS to report information about a map's contents, or the results of an analysis on one or more maps, back to the user. The user can also develop macros specific to his needs to prepare other types of reports (see past issues of the newsletter *GRASSClippings*).

11.1. Reports on Contents of Single or Multiple Maps

The following GRASS commands report on the contents of one or more maps.

d.measure - Measures the lengths and areas of features drawn by the user in the active display frame on the graphics monitor.

d.rast.arrow - Draws arrows representing cell aspect direction for a raster map layer.

d.rast.num - Overlays cell category values on a raster map layer displayed to the graphics monitor.

d.what.rast - Allows the user to interactively query the category contents of multiple raster map layers at user-specified locations within the current geographic region.

d.what.vect - Allows the user to interactively query the category contents of multiple (binary) vector map layers at user-selected locations within the current geographic region.

d.where - Identifies the geographic coordinates associated with point locations in the active frame on the graphics monitor.

r.cats - Prints category values and labels associated with user-specified raster map layers.

r.describe -	Prints terse list of category values found in a raster map layer.
r.info -	Outputs basic information about a user-specified raster map layer.
r.profile -	Outputs the raster map layer values lying on user-defined lines.
r.report -	Reports statistics for raster map layers.
r.stats -	Generates area statistics for raster map layers.
r.transect -	Outputs raster map layer values lying along user-defined transect lines.
r.volume -	Sums cell values within clumps and calculates volumes and centroids of patches or clumps.
r.what -	Queries raster map layers on their category values and category labels.
v.area -	Display GRASS area and perimeter information for GRASS vector map.
v.stats -	Displays information about a user-specified GRASS vector file.