Grass Tutorial

Moritz Lennert

mlennert@club.worldonline.be

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by Moritz Lennert

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Geographic Resources Analysis Support System Tutorial

(Please note, the current version only outlines the intended contents, pages may be missing!)

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Chapter 1. About this tutorial

This tutorial (or maybe it should rather be calles manual ?) should help you get started with GRASS[1]. It gives basic explanations of how GRASS functions and links to the relevant man pages and other documentation.

Several chapters in this tutorial contain content taken from the english translation of Markus Neteler's GRASS Handbook[2], (c) 1996-2001, Markus Neteler. I have not included explicit references each time I've used excerpts, but it is the most important source of text in these pages.

Notes

1. http://grass.itc.it/
2. http://grass.itc.it/gdp/handbuch/index.html

Chapter 2. What is GRASS ?

GRASS - Geographic Resources Analysis Support System is a general GIS supporting processing, analysis and display of raster, vector, site and imagery data, geospatial simulations and visualization.

For a general introduction, see the GRASS First Time User Page[1].

Overview of *GRASS* versions currently available:

- *CVS GRASS6* - continuously updated developers version - see GRASS CVS page[2]
- *GRASS6.1* - under development, see GRASS6 page[3]
- *GRASS6.0* - current stable release, see GRASS6 page[4]
- *GRASS4.3*- last non-floating point release - see GRASS4.3 release page[5]
- *GRASS4.1*- latest official CERL release 1991 - see GRASS4.1 release page[6]

GRASS is an Open source sofware released under the GNU General Public Licence[7] - it is therefore free with protection of the authors' rights. With its 1.5 million lines of C code, it is one of the largest Open source projects.

Notes

1. http://grass.itc.it/intro/firsttime.php
2. http://grass.itc.it/devel/cvs.php
3. http://grass.itc.it/grass60/index.php
4. http://grass.itc.it/grass60/index.php
5. http://grass.itc.it/announces/4.3release.info.html
6. http://grass.itc.it/announces/4.1release.info.html
7. http://www.gnu.org

Chapter 3. Credits

- History of GRASS[1]
- Credits[2]
- Current development team[3]

Notes

1. http://grass.itc.it/devel/grasshist.html
2. http://grass.itc.it/devel/grasscredits.html
3. http://freegis.org/cgi-bin/viewcvs.cgi/~checkout~/grass/AUTHORS

Chapter 4. Hardware and software requirements

Hardware

A workstation running some flavor of UNIX like Solaris, IRIX, GNU/Linux, BSD, Mac OS X. GRASS also runs on on Win32 within the Cygwin environment[1]. As a minimum, you should have at least 500 Mb for data and 32 Mb RAM. However this will allow you only a very limited usage of GRASS (although see here[2] for GRASS on handhelds). For a serious usage of GRASS you will need 128MB at the very least. Obviously, a good video card is a must for cartography, ideally with 3D support.

Basic Software

- C-compiler (cc, gcc, egcs, ...)

  gcc: http://www.gnu.org/software/gcc/gcc.html

- GNU make is recommended

  http://www.gnu.org/software/make/make.html

- zlib compression library (already installed on modern systems)

  It is used to internally compress GRASS raster files: libz: http://www.gzip.org/zlib/

- lexical analyzer generator (flex),

  (lex is no longer supported, please use flex instead) - flex: http://www.gnu.org/software/flex/flex.html

- parser generator (yacc, bison)

  bison: http://www.gnu.org/software/bison/bison.html

- libncurses4.x/5.x (already installed on modern systems)

  http://www.gnu.org/software/ncurses/ncurses.html

  ftp://ftp.gnu.org/pub/gnu/ncurses/

- dgm/gdbm (dbm.h): GNU dbm is a set of database routines that use extendible hashing and works similar to the standard UNIX dbm routines. Currently not required.

  http://www.gnu.org/software/gdbm/gdbm.html

- X11 window system for graphical output, development libraries (X development libraries, in some linux distributions they are separate packages)

  http://www.xfree.org

  (winGRASS: As alternative a generic MS-Windows driver is under construction which does not require X11)

Optional software

- Tcl/Tk 8.x libraries (they include 'wish') to use TclTkGRASS Interface and to compile src.contrib/GMSL/NVIZ2.2/

  http://tcl.sourceforge.net/

- Mesa-3.x (openGL clone) required for NVIZ2.2 (if your OS / graphic card libraries don't come with own OpenGL libraries)

  http://mesa3d.sourceforge.net/

- FFTW (library for computing the Discrete Fourier Transform) required for i.fft and i.ifft modules

  http://www.fftw.org

- LAPACK / BLAS (libraries for numerical computing) required for GMATH library (GRASS numerical lib)

  http://www.netlib.org/lapack/ (usually present in Linux distros)

  Note: the support is intended for future module implementations

- libpng (for r.in.png, r.out.png), usually already installed.>

  http://www.libpng.org/pub/png/libpng.html

- libjpeg (for r.in.tiff, r.out.tiff), usually already installed.

  http://www.ijg.org[17]

  ftp://ftp.uu.net/graphics/jpeg/

- libtiff (for r.in.tiff, r.out.tiff), usually already installed.

  http://www.libtiff.org

- libgd (for PNG driver), preferably GD 2.x.

  http://www.boutell.com/gd/

- netpbm-tools/libraries (for r.in.png/r.out.png), usually already installed.

  (please look at any decent software mirror near you!)

  http://netpbm.sourceforge.net/

  http://www.sourceforge.net/projects/netpbm/

- PostgreSQL libraries (for the PostgreSQL database interface)

  http://www.postgresql.org

- Unix ODBC (for the ODBC database interface)

  http://www.unixodbc.org

- Only required for "xanim" and "ogl3d": the Motif or Lesstif libraries
  http://www.lesstif.org

- r.in.gdal requires GDAL - Geospatial Data Abstraction Library
  http://www.remotesensing.org/gdal/

- R language (for the R language interface)
  http://cran.r-project.org

- FreeType2 (for d.text.freetype)
  http://www.freetype.org/

Notes

1. http://www.cygwin.com
2. http://grass.itc.it/platforms/grasshandheld.html
3. http://www.gnu.org/software/gcc/gcc.html
4. http://www.gnu.org/software/make/make.html
5. http://www.gzip.org/zlib/
6. http://www.gnu.org/software/flex/flex.html
7. http://www.gnu.org/software/bison/bison.html
8. http://www.gnu.org/software/ncurses/ncurses.html
9. ftp://ftp.gnu.org/pub/gnu/ncurses/
10. http://www.gnu.org/software/gdbm/gdbm.html
11. http://www.xfree.org
12. http://tcl.sourceforge.net/
13. http://mesa3d.sourceforge.net/
14. http://www.fftw.org
15. http://www.netlib.org/lapack/
16. http://www.libpng.org/pub/png/libpng.html
17. http://www.ijg.org/
18. ftp://ftp.uu.net/graphics/jpeg/
19. http://www.libtiff.org
20. http://www.boutell.com/gd/
21. http://netpbm.sourceforge.net/
22. http://www.sourceforge.net/projects/netpbm/
23. http://www.postgresql.org
24. http://www.unixodbc.org
25. http://www.lesstif.org
26. http://www.remotesensing.org/gdal/
27. http://cran.r-project.org

28. http://www.freetype.org/

Chapter 5. Basic UNIX reference

Since GRASS runs in a UNIX / GNU / Linux environnement, general knowledge of basic UNIX commands is recommended. Here are a few links to introductions and tutorials:

- Linux Cookbook[1]
- The Linux Users' Guide[2]
- Unix commands reference card[3]
- Introduction to Linux[4]

Notes

1. http://www.dsl.org/cookbook/
2. http://www.ibiblio.org/pub/Linux/docs/linux-doc-project/users-guide/
3. http://www.indiana.edu/~uitspubs/b017/
4. http://www.tldp.org/LDP/intro-linux/html/index.html

Chapter 6. Download and Install

Get GRASS from the Download Page[1] on the server in Italy or from one of the Mirror Sites[2].

For a very thourough introduction about GRASS (and Linux) installation, please see A.P. Pradeepkumar's Absolute beginner's Guide to GRASS Installation (PDF, 277K)[3].

Packages of GNU/Linux Distributions

Binary packages have been created for major GNU/Linux distributions . The can be downloaded at GRASS downlaod page[4]

Mandrake

In Mandrake 9.0 and later, GRASS is included in the contribs. To install use the Software Installer in the Mandrake Control Center, or run 'urpmi grass' as root.

Debian

GRASS is included in Debian testing and unstable. You may also check Debian GIS repository[5]

SuSE

SuSE rpms are avalaible on GRASS download page.

Live CD

You can buy the FreeGIS CD[6] which contains GRASS and much more.

Compilation of source code

You can also download and compile the entire source code yourself. This allows you to have access to the code and modify it if you would like to.

The source is more or less platform independent and is available at http://grass.itc.it/download/index.php. For GRASS 6.0 get the grass-6.0.0.tar.gz file, put it into the directory of your choice and decompress it with:

gunzip grass6.0.0.tar.gz; tar -xvf grass6.0.0.tar

or

tar -xvzf grass6.0.0.tar.gz

Then follow the installation instructions[8] also included in the source code archive you downloaded. Also, don't forget to read the list of required software [9] or Chapter 4 in this tutorial.

Notes

1. http://grass.itc.it/download/index.php
2. http://grass.itc.it/mirrors.php
3. http://grass.itc.it//gdp/tutorial/abs_beginners.pdf
4. http://grass.itc.it/download/index.php
5. http://pkg-grass.alioth.debian.org/cgi-bin/wiki.pl
6. http://www.freegis.org/cd-contents.en.html
7. http://grass.itc.it/download/index.php
8. http://grass.itc.it/grass60/source/INSTALL

9. http://grass.itc.it/grass60/source/REQUIREMENTS.html

Chapter 7. How to Quickstart GRASS

This chapter aims at giving a newcomer in GRASS a very hands-on introduction in order to give him the opportunity to very quickly take first tentative steps in GRASS. This does not replace a throrough study of the rest of the documentation, but should help relieve the frustrations that many newbies feel at the first contact with GRASS. It will cover GRASS 6.0, so if you have an earlier version, consider upgrading.

This introduction assumes that you have already successfully installed GRASS, but that you have not yet launched a GRASS session successfully. If you haven't installed GRASS, yet, please have a look at Chapter 6. For newbies, the binary installation is recommended. If you are unfamiliar with the UNIX or GNU/Linux environment, please go to Chapter 5 first and follow some of the links there.

Before going any further, you will have to create the GRASS database:

1. Find a place on your disk where you have write access and that has enough diskspace to hold your decompressed data.
2. Create a subdirectory that will hold the general GRASS database (e.g. "mkdir /data/GRASSDATA" or "mkdir /home/yourlogin/GRASSDATA").

Now you can go on. The following subsections will cover different potential "scenarios", each representative of the situations in which a new user might turn to GRASS:

- If you have a GRASS database, either because someone gave you one, or because you downloaded sample data such as the Spearfish sample dataset[1] (see here[2] for other data sets), then see the Section called *You have a GRASS database*.
- If you have a georeferenced data file (raster, vector or sites) and know its geographical projection, its extension, and its resolution (for raster), then see the Section called *You have a georeferenced data file, and know its geographical coordinates*.
- If you have a georeferenced raster file, but do not know its projection, extension, or resolution, then see the Section called *You have a georeferenced raster file, but don't know its geographical coordinates*.
- If you have a non-georeferenced data file (example scanned map), then see the Section called *You have a non-georeferenced data file*.
- Other, see the Section called *Other situations*

You have a GRASS database

You have a tar ball (*.tgz, *.tar.gz, *.tar) with an already prepared GRASS location. Here are the steps to follow:

1. Enter the GRASS database directory you created above and untar your data file in there (e.g. "tar xvzf /path/to/where/you/downloaded/yourdatafile.tgz"). This should create a directory containing the sample location (e.g. spearfish60), with several subdirectories, each of these representing a mapset. There should be at least one, called "PERMANENT" (note the names of the others). Don't touch anything in this directory.
2. Go back to your home directory ("cd") and start GRASS ("grass").
3. First specify in the Database field the absolute path to the directory you created above (e.g. "/data/GRASSDATA"). You can now choose the location. If you download sampledata, it will be spearfish60. Now, you should see at least PERMANENT in the mapsets list. You can create a new mapset by enter its name in the left field and click on "Create..." button. Select one them on the mapsets list. Click on "Enter GRASS" button.
4. The GIS Manager should start automatically.

5. See Chapter 8 for the next steps.

You have a georeferenced data file, and know its geographical coordinates

You have a file in a georeferenced format (GeoTiff, shape, etc) and have all the information concerning the projection the data is in, its geographical extensions, and, if it is a raster file, its resolution. You will have to create a location according to that information. Assuming that the file is in your home directory, here's what you have to do (if it somewhere else, just change the path to the file when entering the relevant commands)):

1. Create a new location according to the information you have and the steps described in Chapter 16.
2. Once you have entered GRASS, you can import the file with the appropriate module as described in Part VI in *Grass Tutorial*. (You can use the graphical user interface for most imports: start it with **d.m&**).
3. When you have finished the importation process, see Chapter 8 for the next steps.

You have a georeferenced raster file, but don't know its geographical coordinates

Someone gave you a geocoded raster file (GeoTiff, shape, etc) or you downloaded it from somewhere, but you have no information as to its geographical projections, its extension, or its resolution. You, therefore, do not know how to create a location that is appropriate for this data. Here's what you can do:

1. Check here[3] if the format your file is in can be imported and georeferenced by GDAL. If it can't, see if you can convert it to any of the supported formats. If that is not possible, you're out of luck and will have to move on to the Section called *Other situations*.
2. Start GRASS ("grass").
3. Click on "Create New Location".
4. In the terminal screen you see, enter a name for a temporary location (e.g. "LOCATION: temp"), leave the mapset at its default (your login name) and set the database to the directory you created at the very beginning (e.g. "/data/GRASSDATA").
5. When told that the "LOCATION (temp) - doesn't exist" and asked whether you would like to create location (temp), you answer "yes, please" (well actually you just press 'y'.)
6. You press 'y' again pretending that you have all the information listed on the next screen as being absolutely necessary.
7. When asked to specify the coordinate system, chose 'a' for "x,y" and then 'y' (or just ENTER) for "yes".
8. Enter a description of your location, such as "temporary x,y location for import", press ENTER and confirm your beautiful title with 'y' or ENTER.
9. Don't even look at the next screen (entitled "Define the default region"), just press ESC-ENTER to get it out of your sight as quickly as possible. Again, confirm your "choice" with 'y' or ENTER, plus another ENTER to congratulate GRASS for having created your new location.

10. Don't panic because you've been returned to the very first screen. It's normal. Press ESC-ENTER, and life in GRASS can begin !
11. You are in a shell that is just like any other UNIX shell, only for the GRASS prompt and some environment variables that have been added (but that you don't have to worry about).
12. Now we will use the magic of r.in.gdal[4]:[5] in the command line type "r.in.gdal in=RasterFile out=GRASSRaster location=NewLocation", where 'RasterFile' is the name (and, if the file is not in the current directory, the path) of the raster file you want to import, 'GRASSRaster' is the name you want that map to have in GRASS, and 'NewLocation' the name of a new location **r.in.gdal** will create automatically for the new map, and which will contain all the geographical information (projection, extension, resolution) included in the orginial raster file.

    You may also use v.in.ogr[7] instead of **r.in.gdal**if you have vector data. GRASS need to be build with OGR[8] support to use this command.

13. If all goes well (i.e. no error messages), you now have to enter the new location just created automatically by **r.in.gdal** or **v.in.ogr**. Since you cannot change location within a running GRASS session, you have to leave GRASS ("exit").
14. Restart GRASS. This time it should come up with the Tcl/Tk welcome window. The window will list the available locations and mapsets in your GRASS-Database. Chose the new location just created by r.in.gdal/v.in.ogr ('NewLocation'), and chose the mapset that is called after your login name. Then click "Use Selection".
15. Congratulations, you made it (I hope !). Now you can move on to Chapter 8 to actually do something with your map.

You have a non-georeferenced data file

You scanned a map and now have a non-georeferenced raster file, Or you downloaded a nice PNG file of a political world map from the internet. Or you drew a map of your garden in the GIMP and now want to use it to manage your plantings. In other words, either you do not have the georeferencing information of this map (and it is not included in the file format) or you do not care about projection for your use of the map. This section is for you.

Before going any further though, a word of advice: if you only plan on viewing the map, and not doing any real work concerning geographical *information* (i.e. linking data with geographical coordinates), then maybe GRASS is not the right tool for you. GRASS is a full-fledged GIS, and not a map viewer, and using it just to quickly view some maps would probably be overkill.

Since your map is not georeferenced, you can import it into a simple x,y location, i.e. where the coordinates directly designate pixels on the screen. In order to do so, just follow the steps described in the previous section, up to the **r.in.gdal** call. However, in this case you will not use the the 'location=' option, but just type: "r.in.gdal in=RasterFile out=GRASSRaster" (you can also use one of the other raster import commands[9]). That's it ! In order to learn how to view your map and do other basic operations, see Chapter 8.

If you have a scanned map and you have access to the geographical information concerning the original paper map, then you should read Chapter 28.

Other situations

So, you have a file, without much information about it, but you think (or know) it should be georeferenced. For example, someone sent you an ESRI shape file containing a map you would like to work on. Or you received a raster in a binary format that is not supported by the GDAL library. Here are some tips on what you might want to do, depending on the usage you will make of the file:

- Ask the person who sent you the maps to give you more information.
- Think about the data. What is it displaying (political boundaries of countries, a satellite image of jungle areas, etc), what is its rough geographical extension (the World or your hometown) ? Where does the data come from (NASA, a personal digitization, etc). All these factors might give you a lead about the structure of the data.
- Try to load your data into different locations (see Chapter 16 for the creation of a location) using widely used projection systems for the area your data is supposed to cover. For example, UTM is widely used in North America, while Gauss-Krueger is often used in Europe. A lot of the basic shapefiles given out by ESRI are in latitude-longitude "projection". You might want to try the latter first and see how the data looks. Is it distorted ? Are vector areas not closed ?
- You can also start by creating a simple "x,y" location (see the Section called *You have a georeferenced raster file, but don't know its geographical coordinates* on how to create such a location). Import your data with the appropriate module (see Part VI in *Grass Tutorial* and then explore it with the commands explained in Chapter 8.
- Good luck !

Notes

1. http://grass.itc.it/sampledata/spearfish_grass60data.tar.gz
2. http://grass.itc.it/download/data.php
3. http://www.remotesensing.org/gdal/formats_list.html
4. http://grass.itc.it/grass60/manuals/html60_user/r.in.gdal.html
5. If you compiled GRASS yourself, be sure to also have installed the

   6. http://www.remotesensing.org/gdal/
   , otherwise r.in.gdal will not work. This is also true for v.in.ogr that require OGR libraries.
6. http://www.remotesensing.org/gdal/
7. http://grass.itc.it/grass60/manuals/html60_user/v.in.ogr.html
8. http://www.gdal.org/ogr/
9. http://grass.itc.it/grass60/manuals/html60_user/raster.html

Chapter 8. The Most Important Commands to Get Started

So, you've managed to create a GRASS database and location and to import some data, and now you want to actually do something with it ? This chapter will help you get going very quickly with some of the basic operations in GRASS. Again this is not to replace further going sections later in this documentation, but only to allow you to plunge into the fun as quickly as possible.

Basic tasks and their commands

Using the GUI

GRASS has a graphical user interface written in Tcl/Tk, the GIS Manager. This functions as a front end to all the GRASS modules. To start it type **d.m&** (the '&' allows you to keep on using the GRASS shell). The GIS Manager generate automatically a GUI for every modules. You can browse menus or type the name of a command without argument to lauch them.

For more information, see Chapter 11.

Managing your maps

In order to list, copy and remove your maps, you can use g.list[1], g.copy[2], and g.remove[3]. In the GIS Manager, these commands are in the **GIS->Manage maps and grid3D files** menu.

For more information, see Chapter 17.

Setting the region

Before dealing with anything concerning your map, you should make sure that the region is set correctly. To do so, use the command g.region[4]. Type **g.region vect=NameOfYourVectorMap** or **g.region rast=NameOfYourRasterMap**. This will set the 'current' region to the extension and the resolution of your map. Use **g.region -p** to display the current region settings.

You can access region settings in **GIS->Region** menu of the GIS Manager.

For more information, see Chapter 12.

Displaying

The easiest way to do this is with the `GIS Manager` that you can start with the command d.m&[5] (the '&' allows you to keep using the GRASS shell at the same time). You can add raster or vector layer using appropriate button on the buttons bar - respectively 10th and 11th button from left. After, you can choose the layer name by clicking on the "Raster name:" or "Vector name:" button in the lower part of the interface. Click on the first button of the buttons bar to display selected layers.

If you are more of the command line type, or don't want to use d.m for other reasons, GRASS provides you with all the commands needed for a happy experience. Launch a GRASS monitor with d.mon x0[6]. Then, run d.rast[7] or d.vect[8], depending on the type of map you want to display: **d.rast NameOfYourRasterMap** or **d.vect NameOfYourVectorMap** and your beauty should come up on the monitor. If you wish to erase the GRASS monitor use d.erase[9].

All these commands can also be launched from the GIS Manager. To start a monitor go to **Display->Start displays->X0**. To display a map go to **Display->Display raster/vector maps**. To erase the monitor go to **Display->Erase active display/frame to selected color**.

If you imported a raster file and GRASS created three files named `NameOfYourRaster.1`, `NameOfYourRaster.2`, and `NameOfYourRaster.3`, these probably represent the three bands of an RGB image. In that case, change the color map of these three files to greyscale (thus making the "intensities" of grey represent the "intensities" of the respective colors), using r.colors[10]. For each of the three maps type **r.colors map=NameOfYourRaster col=grey**. Then you can use d.rgb[11] to display the image: **d.rgb r=NameOfYourRasterMap.1 g=NameOfYourRasterMap.2 b=NameOfYourRasterMap.3**. In the GIS Manager go to **Raster->Manage map colors->Set colors to predefined color tables** and chose 'grey' in the list "Type of color table". Then display with **Display->Display raster maps->Display RGB overlays**.

For more information, see Chapter 23.

Zooming and panning

Use d.zoom[12] for zooming and panning. (Beware: this resets your region settings !)

Getting help

You can get help with the g.manual[13] command.

Exiting

If you wish to exit GRASS, close the open monitors either by clicking on the close button or by using d.mon stop=x0[14], replacing 'x0' with the name of whatever monitor you opened. In the GIS Manager go to **Display->Stop displays**. Then you can simply type **exit** in the command line and GRASS will close down.

So much for some very basic GRASS usage. For the rest, keep on reading this tutorial, have a look at the rest of the GRASS Documentation Project[15] and study the GRASS manual pages[16].

Notes

1. http://grass.itc.it/grass60/manuals/html60_user/g.list.html
2. http://grass.itc.it/grass60/manuals/html60_user/g.copy.html
3. http://grass.itc.it/grass60/manuals/html60_user/g.remove.html
4. http://grass.itc.it/grass60/manuals/html60_user/g.region.html
5. http://grass.itc.it/grass60/manuals/html60_user/d.m.html
6. http://grass.itc.it/grass60/manuals/html60_user/d.mon.html
7. http://grass.itc.it/grass60/manuals/html60_user/d.rast.html
8. http://grass.itc.it/grass60/manuals/html60_user/d.vect.html
9. http://grass.itc.it/grass60/manuals/html60_user/d.erase.html
10. http://grass.itc.it/grass60/manuals/html60_user/r.colors.html
11. http://grass.itc.it/grass60/manuals/html60_user/d.rgb.html
12. http://grass.itc.it/grass60/manuals/html60_user/d.zoom.html
13. http://grass.itc.it/grass60/manuals/html60_user/g.manual.html
14. http://grass.itc.it/grass60/manuals/html60_user/d.mon.html
15. http://grass.itc.it/gdp/
16. http://grass.itc.it/grass60/manuals/html60_user/

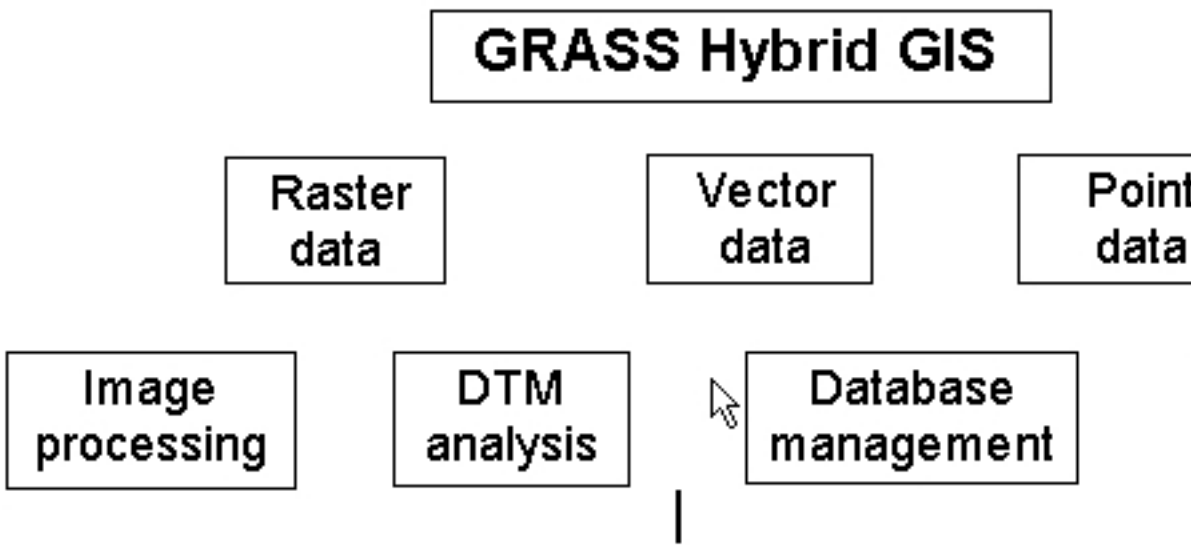
Chapter 9. GRASS structure

Generally speaking, GRASS is a normal user program like many others. It comes with a graphical user interface (GUI) that allows GRASS usage through the mouse. Parallel to that, GIS commands can be entered in the GRASS terminal window. Nevertheless, the program structure is somewhat different to normal user programs: after the start-up of GRASS the GRASS commands (typically called GRASS modules) are at the same level as the other UNIX commands, meaning that all UNIX commands are also available in the terminal window where GRASS has been started. This concept allows the use of the entire might of UNIX and the programming of powerful procedures while working with GRASS. Newcomers to GRASS might have to get used to this structure, but they will quickly realize its advantages.

In GRASS GIS data are stored in a directory structure. Before beginning to work with GRASS, the user has to create a "GRASS data subdirectory" (called GRASS database) and specify it later within GRASS. In this directory, GRASS organizes its data automatically through subdirectories. A new subdirectory tree is created for each new project (called "location") within the database. The organisation of the data should be left to GRASS. All file operation such as renaming or copying maps involve several internal files and should thus always be done only with GRASS commands. Manual interventions are acceptable just in exceptional situations. The GRASS graphical output, in other words the map display window, is no "normal" window but displays geographical data with coordinates. This graphical output window (called GRASS monitor) can be managed with the GRASS d.mon command. Additonally TclTkGRASS allows the configuration and management of these windows.

A few more words about GRASS terminology: as mentioned, a project area is called location in GRASS. It is defined by its geographical boundaries with information about coordinates and the map projection. Within this location, area subsections, called mapsets, can be created. Often only one mapset as large as the location is used. Multiple mapsets may be interesting for working groups. Here the "PERMANENT" mapset (reserved name) contains maps common for the group, while each team member works in his/her own mapset. The database is simply called database in GRASS.

Within the database, data is divided into raster, vector and site (point) data, allowing differential treatment:



Chapter 10. GRASS commands

The command name indicates its use: first letter indicates data format or general functionality followed by a dot and a short word indicating the task that the command performs:

- d.* - display commands for graphical screen output: d.rast, d.vect, d.sites, d.mon
- g.* - general file management commands: g.list, g.copy
- i.* - image processing commands
- r.* - raster processing commands: r.slope.aspect, r.mapcalc
- v.* - vector processing commands: v.digit, v.to.rast
- s.* - site processing commands (point data): s.univar, s.surf.rst
- m.* - miscellaneous commands: m.in.e00
- p.* / ps.* - map creation ('print') commands
- ... - unix scripts (some ending in .sh, some imitating GRASS module names)

Almost all modules can be used either directly on the command line (module call and parameters together on one line) or interactively, i.e. you can call each module without parameters, then you will be prompted for required information like map names etc.

You can read the manual pages of the commands of GRASS 5.0 online[1] or with the g.manual[2] command in a running GRASS session (Help->Manual pages in TclTk-GRASS). There is also an (incomplete) one-line reference[3] containing a short explanation of many commands.

Notes

1. http://grass.itc.it/gdp/html_grass5/index.html
2. http://grass.itc.it/gdp/html_grass5/html/g.manual.html
3. http://grass.itc.it/gdp/html_grass5/grass_commandlist.html

Chapter 11. Graphical User Interface

The "TclTkGRASS" GUI which allows mouse usage is simply an extension without own GIS functionality. TclTkGRASS offers graphical access to important GRASS modules and makes working with GRASS easier. However, don't forget that it is incomplete and that there are many more modules available than are present in the TclTkGrass menus. Also beware that some modules that are present lack some of their command line options in their tcltkgrass window.

If TclTkGRASS was not started automatically during GRASS startup, you can do so at the GRASS prompt with the command **tcltkgrass&**.

Chapter 12. The GRASS Region

What is the region

The "region" is a cornerstone concept in GRASS. If you want to be able to use GRASS to its full potential, you have to understand it. In fact, it is so important that you should know about it even if you only plan some light usage of GRASS. This chapter is an attempt at explaining as clearly as possible what the region is and what its effects are. It will also, hopefully, help you understand the usefulness of the region in GRASS.

The region defines the geographic area in which GRASS should work. It is characterized by several parameters:

- geographical projection (e.g. UTM, latitude-longitude, Gauss-Krueger, etc)
- geographical extension, i.e. the North/South/East/West limits of the area covered
- number of columns and number of rows for the data
- resolution, i.e. the extension divided by the number of rows (N-S resolution), respectively columns (E-W resolution).

The default values of these parameters for a given location are stored in the `DEFAULT_WIND` file in the `PERMANENT` mapset of that location. The current region settings are stored in the `WIND` in the current mapset. The stored values will stay valid, even if you exit GRASS and restart it.

Why care about the region

As said above, the region defines the extension and resolution of the data on which most GRASS commands should work. But what does that mean ?

For instance, if the region is set to a smaller extension than that of the map you are working on, a display command for that map (such as **d.rast**) will only show the portion of the map that is contained in that region. Many other commands will also only work on that region, as for example many of the export commands, or many of the raster development modules. This allows working on only a portion of the map, thus not using up your computer's ressources for the rest of the map. Or you can export only the portion of a map that really interests you.

In a similar way, you can reduce the resolution of the region in order to use less machine resources. For example, you might want to convert a vector map to raster, but do not need the raster in very high resolution, as, for example, if you want to create a thematic map of the world, where the exact contours of the countries are not very important. You can, therefore, change the region settings to a lower resolution before launching the conversion, so that it takes less time and memory.

In general, you always have to be careful to assure that the region is set correctly before doing any work on your map. A typical problem of newcomers to GRASS is that they import a map and then try to display it, but only see an empty GRASS monitor. This is almost always due to wrong region settings which make the map fall outside the area currently covered by the region.

Ideally, the default region of a location should encompass the entire area covered by all the maps in that location. So if you reset your region to the default, subsequent commands should always cover your entire location. If however, you import a map that is larger than the default region, you can still set the current region to that new map's settings by using (see below for an explanation of these commands) **g.region rast=name** or **g.region vect=name**. However, whenever you use **g.region -d** you will reset your current region to the default which does not contain the new, larger map.

How to work with the region

The main tool for working with the region is the g.region[1] command. Read the man page thoroughly to get aquainted with all its possibilities. Here are some of the most common usages:

g.region -p

Print current region settings.

g.region -d

Reset current region to default for location.

g.region rast=NameOfARasterMap

Set the current region to the coordinates of the raster file

g.region vect=NameOfAVectorMap

Set the current region to the coordinates of the vector file

g.region save=filename

Save the current region settings into the file `filename`

g.region region=filename

Set the current region to the coordinates saved in `filename` (created with **g.region save=filename**).

g.region n=value s=value e=value w=value res=value

Set the northen, southern, eastern, western edges and the resolution to the respective values.

g.region

Will bring up a menu allowing you to access all of the options interactively.

d.zoom

You can also set the region values (except for the resolution) interactively with the mouse on the current monitor using d.zoom[2].

All these functions can also be accessed in Tcltkgrass via **Region->Manage region**.

How to change the default region

Sometimes you would like to import a map that is larger than (or even completely outside of) the default region of the existing location. You can do that without any problem, but in order to visualize it, you will have to use **g.region rast** or **g.region vect** in order to adapt the current region to the map. However, anytime you use **g.region -d** the region will be reset to the old setting and your map will not be visible.

Here's a (somewhat quick and dirty) solution to this problem (hopefully g.region will be modified to include this as an option, one day): open a monitor (see Chapter 22), display all you maps (see Chapter 23), zoom and pan until you can see all you maps in the screen (if you know that the extension of one map englobes all the others, you can also use **g.region rast** or **g.region vect**, followed by **d.erase** before displaying all your maps). Once you are sure that the currently active region contains all your maps, you can make it into the default region as follows:

- Begin by making a backup copy of your default region: **cp $GISDBASE/$LOCATION_NAME/PERMANENT/DEFAULT_WIND**

~/default_region.bak. If anything goes wrong you can reset to your old default region with **cp ~/default_region.bak $GISDBASE/$LOCATION_NAME/PERMANENT/DEFAULT_WIND**.

- Make the current region into the default region with **cp $GISDBASE/$LOCATION_NAME/$MAPSET/WIND $GISDBASE/$LOCATION_NAME/PERMANENT/DEFAULT_WIND**.
- Now, whenever you use **g.region -d**, the region will be set to your new default region

Notes

1. http://grass.itc.it/gdp/html_grass5/html/g.region.html
2. http://grass.itc.it/gdp/html_grass5/html/d.zoom.html

Chapter 13. Set-up your GRASS database

Before beginning to work with GRASS for the first time, you have to create a subdirectory (the GRASS database, where GRASS stores its spatial data) in your home directory. For team work, it is better to create it in a partition /data where everybody in a team has permissions rather than in your home directory.

Within the database, the data are stored in the following directory structure:

GRASS database:

- grassdata (user/administrator has to create this directory)

For each project a new subdirectory called location is created automatically by GRASS:

- grassdata/spearfish (this subdirectory is created by GRASS)

Each user (team member) working on this project has her own mapset:

- grassdata/spearfish/maria

There is a special mapset called PERMANENT where maps common for the group are stored and protected from overwriting. Team members have access to each other's data but they cannot delete or modify data in a mapset that they do not own.

Chapter 14. Start running GRASS

GRASS can be run in 3 modes (you can combine them any time)

- TclTk interface
- command line:**r.slope.aspect myelevation slope=myslope aspect=myaspectGRASS**
- interactive parser: **r.slope.aspect** followed by dialogue

Start GRASS by typing:

$>grass5

(See the GRASS5 startup man page[1] for details about start-up options.)

You will then be asked to provide the database directory (only the first time you start GRASS) and either choose from the availabe locations and mapsets or create a new location (see below on how to do this).

Once at the GRASS prompt you can type any grass or unix commands, and, if it hasn't started up automatically, you can start the TclTkGRASS-GUI by typing **tcltkgrass&**.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/grass5.html

Chapter 15. Planning and constructing a GRASS database

You should take extra care when creating the project area (the location). The structure is determined by the used data.

The following section will demonstrate three methods for importing scanned maps with georeferencing. The first is a resolution-independent way, that is most useful for compensation of scanning errors. In this case you will leave the calculation of GRID RESOLUTION to GRASS. The other two examples are used for calculating the extension and the resolution of a location, supposing that scan errors are non-existant or at least negligeable.

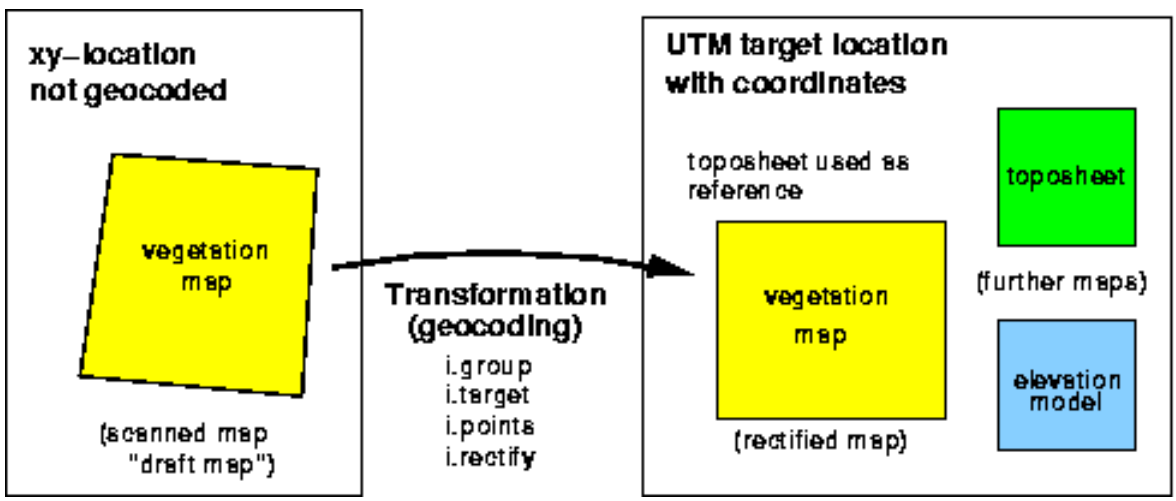
You need to be aware of the relation between geometrical length, scale and geographical extension. This general cartographical relation is also valid when transforming an analog map into a digital map. Since you will most probably be using a scanner (at least to create a backdrop map for the vectorisation within the GIS), these terms are of great importance. Also, you should obviously not forget about copyright restrictions when scanning maps.

When using digital maps that have not only been scanned (for example by a governmental institution) but also already geocoded (or completely digitally created) the data structure and the import are greatly simplified. The data structure can be deduced from the information about the digital map concerning geographical borders and resolution.

General definition of a project area when using scanned maps

During the scanning process it is next to impossible to lay down the map perfectly straight. In consequence, the scanned map will always present a slight rotation away from the northern orientation which is unacceptable when working with GIS. We will, therefore, present as a first method one that requires a little more work and time, but which allows an exact import of maps through the correction of the position with the help of reference points.

This method can be considered a universal method for importing scanned maps. However, in this case you will have to define two project areas with different projections. First, the scanned map is imported into a simple xy location (without projection) and then rectified (geocoded) in a second location with the chosen coordinate system:



Reference points are set on the scanned raw map in the xy location. These reference points are taken from the analogous map and graphically assigned to the scanned

map. The next step is the geocoding of the scanned map through transformation from the xy location to the other location containing a projected coordinate system. Now the map is ready for GIS work.

Example: You have scanned a map at 300dpi. This map we call the “raw map”. In the Section called *Definition of a project area with predefined geographical resolution* you will find the necessary calculation methods in order to determine the correct scanning parameters. It is useful to use a map which already provides marks at the cross sections of coordinate lines. These marks represent important coordinate points for the rectification of the map. You should scan the map a few percentage points larger than needed in GRASS later, so that the marks that are on the edge of the region of interest are clearly visible. Note : The edge of the paper is generally not parallel to the coordinate lines of the projection system. This means that you cannot use the paper edges as location edges.

Before rectifying the raw map, you should first create the location in the actual projection system you will be using for your map, with the required geographical boundaries and resolution (see Chapter 16). Any projection supported by GRASS may be used. You should watch out that the resolution of the target location is not too low since that could cause the digital map to be quite illegible, depending on the scale. It is, therefore, worthwhile to begin by calculating the transformation between scanning resolution and geographical resolution.

Once the new location has been created, you have to leave GRASS again in order to restart it for the creation of the xy location (GRASS cannot switch between locations on-the-fly yet). Later, the rectification module will transfer the map that has been imported into this xy location to the new location and adapt the orientation and the resolution according to the parameters of this projection.

Now the xy location needed for the scanned raw map has to be created. It has to have an extension of at least the number of pixels of the imported map in both directions (x and y). The resolution will be 1 pixel, as usual for xy locations . There actually is a relation to a geographical resolution (in meters, for example), but this relation is of no importance in a location without projection such as xy locations . The "real" resolution (that has been determined through the scanning resolution and the map scale) is relevant only during the transformation into the new projection location .

If the map can only be scanned in several parts due to its size, all map parts are to import into the same xy location . This xy location has to be created large enough in order to hold all parts, i.e. you will have to choose its size according to the largest scanned map part. Since locations sizes can be freely chosen in GRASS, you can define an even larger location "just to be sure". To find out the size of your scanned raw map in pixels, you can use the `ImageMagick` program mentioned in the previous section.

You should by now have created two locations : one xy location for the raw map and one projected location into which the raw map shall be rectified, i.e. geocoded. You will find the instructions on how to import and rectify the scanned map in Chapter 28.

Definition of a project area with predefined geographical resolution

This method for the creation of a location supposes that the boundaries of the project area are known and the scan parameters have to be adapted for a map that is to be scanned (and that can be scanned with no or negligeable errors).

The number of raster cells in a location results from the length and width of the project area as well as the resolution, chosen according to the required precision of the results resolution grid resolution (GRID RESOLUTION).

Example: Let the length of a square location be 1 km, with a wanted resolution of 5m per cell (GRID RESOLUTION). Thus:

1,000m/5m = 200 rows (or columns) => 200*200 raster cells

If, for example, a scan map is to be scanned for this region, it has to contain 200 x 200 rows and columns in order to be imported without distortion. Therefore, in this case, it is the location that determines the scan resolution since the lenght and width of the scanned area are determined by the borders of the location . This is similar for any other data whose resolution also has to be adapted (e.g. digital elevation model with defined raster width).

Now we need to find out which resolution has to be used when scanning, in order to achieve this number of rows and columns at a fixed side length. In this example we will assume a scale of 1:25000 on the map to be scanned. Thus, the location length of 1000m becomes:

100,000cm/25,000 = 4cm,

i.e. 4cm on the map. The scanning resolution of this map that is to be imported is calculated as follows:

raster rows (or columns) / side length of the map = 200 rows (or columns) / 4cm = 50 rows / cm

In dpi (dots per inch, equivalent of rows or columns per inch) this becomes:

50 rows x 2.54 inches = 127dpi

This value has to be set in the scanner software, as well as the section of the map that corresponds to the geographical boundaries of the desired area that is to be scanned. Each map scale will result in a different resolution. The latter has to be chosen big enough in order to keep small map texts legible. While scanning, it is almost impossible to achieve the exact number of rows and columns and a perfect orientation of the map. In this method, one is therefore obliged to rework the scanned map with imaging software (as for example the netpbm-tools, which you can find at http://netpbm.sourceforge.net/.

Now we will look at an alternative method for the definition of the project area depending on the data that is to be processed.

Definition of the project area without a previously defined resolution

This third method for creating a location is to be used when the resolution within the location location can be chosen freely in function of a scanned map (or any other given data). Here the parameters of the location are derived from the data. scanning The image to be imported and the location must have the same number of raster rows and columns. You can find out these values with the help of the `ImageMagick` program, available at http://www.imagemagick.org/. Use its **identify** command or open the scanned map, right-click on it and chose "Image Info".

Which distance in nature corresponds to which length of a raster cell is determined by the chosen scanning resolution. This values needs to be entered as the GRID RESOLUTION during the creation of the location (see coordinates entry form on page locationform). It is important not to change the image size since that would alter the scales within the image.

It is recommended to work with a scanning resolution somewhere between 150 and 300 dpi (color image with 256 colors), with labels on the map being legible. The raster resolution within GRASS (GRID RESOLUTION of the location is derived from that. Here is an example of how to calculate the resolution of a square location . Let us assume a scanning resolution of 300dpi:

300dpi = 300 rows / 2.54cm = 118.11 rows/cm

Let the scale of the scanned map be 1:25,000. Thus, one centimeter on the map is equivalent to 25,000cm in nature. Now let us calculate which distance in nature corresponds to the length of a raster cell:

distance in nature / scanned rows per cm = 25,000cm / 118.11 rows = 211.6 cm/row = 2.12 m/row

This value of 2.12m has to be entered as GRID RESOLUTION Grid resolution during the creation of the location . If you want the GRID resolution to be a whole number, you have to calculate backwards and change the scan resolution respectively. Normally, you should be able to chose this resolution freely up to a maximum value.

Notes

1. http://netpbm.sourceforge.net/
2. http://www.imagemagick.org/

Chapter 16. Set-up your location

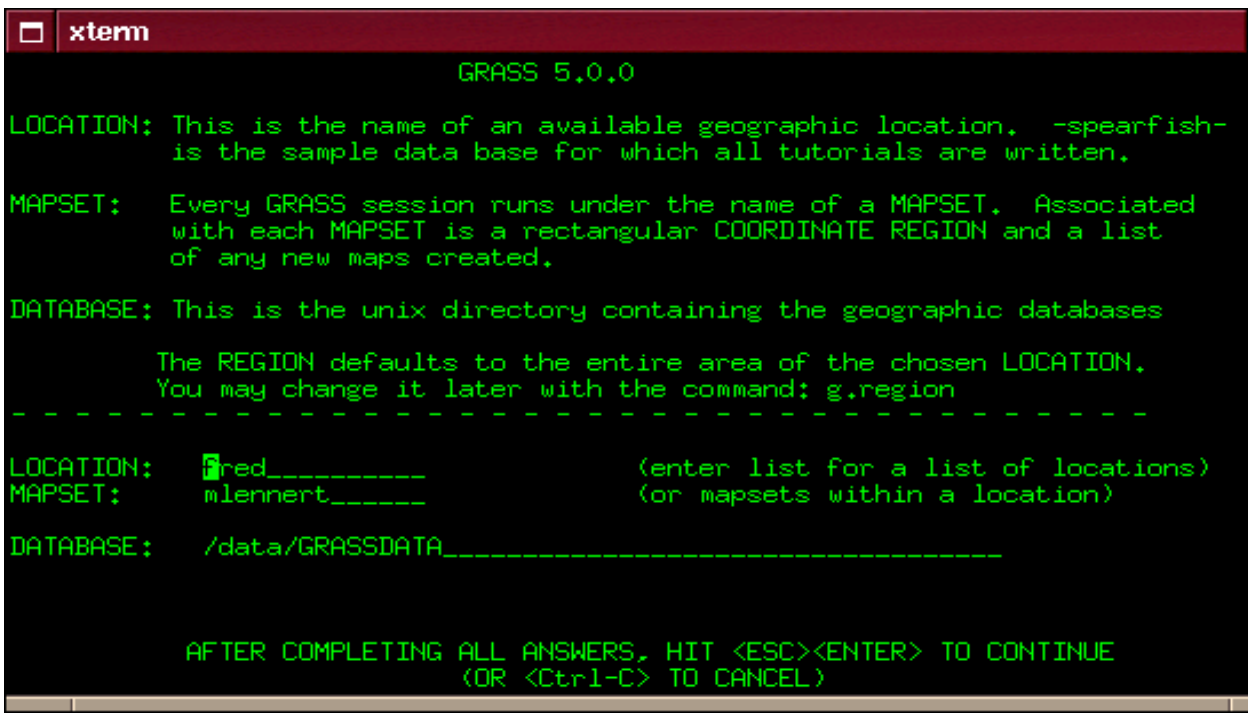
To specify your new location gather out the following information:

- coordinate system for your project area (plane or with projection and ellipsoid)
- minimum and maximum coordinates of the area of interest
- ground resolution

The supported common coordinate systems are here[1].

In general, planning of a database in a Geographical Information System requires some preparation. The user should proceed with care, since the chosen data structure determines the usability of the GIS. Special attention should be accorded to the resolution -- a high raster resolution requires large calculation and memory capacities, a low raster resolution rarely provides acceptable results (this resolution issue is not relevant for vector and sites data). The optimum is somewhere in between and depends on the needs, but also a lot on the input data quality.

The main procedure for creating a location is as follows: first, the GRASS "startup screen" appears. If you started up GRASS with **grass5 -text** (or if this is the first time you start GRASS), the text interface will come up:



There the names of the location (i.e. the entire project area) and the mapset as well as the path to the database need to be entered (e.g. /home/jack/grassdata).

If you enter **list** in one line and then press **ESC - RETURN** to leave this startup mask, GRASS lists all the data available in this category, i.e. all available locations or mapsets. Once you have entered the location, the mapset and the GRASS database, you can continue with **ESC-RETURN**. In order to create a new location, just enter a non-existing location name, and GRASS will ask you if you would like to create a new location.

If you startup GRASS with **grass5 -tcltk**), you will see the following screen:

Click on the button "Create New Location" which will get to the above text screen on which you can enter a non-existing location name and continue with **ESC-RETURN**.

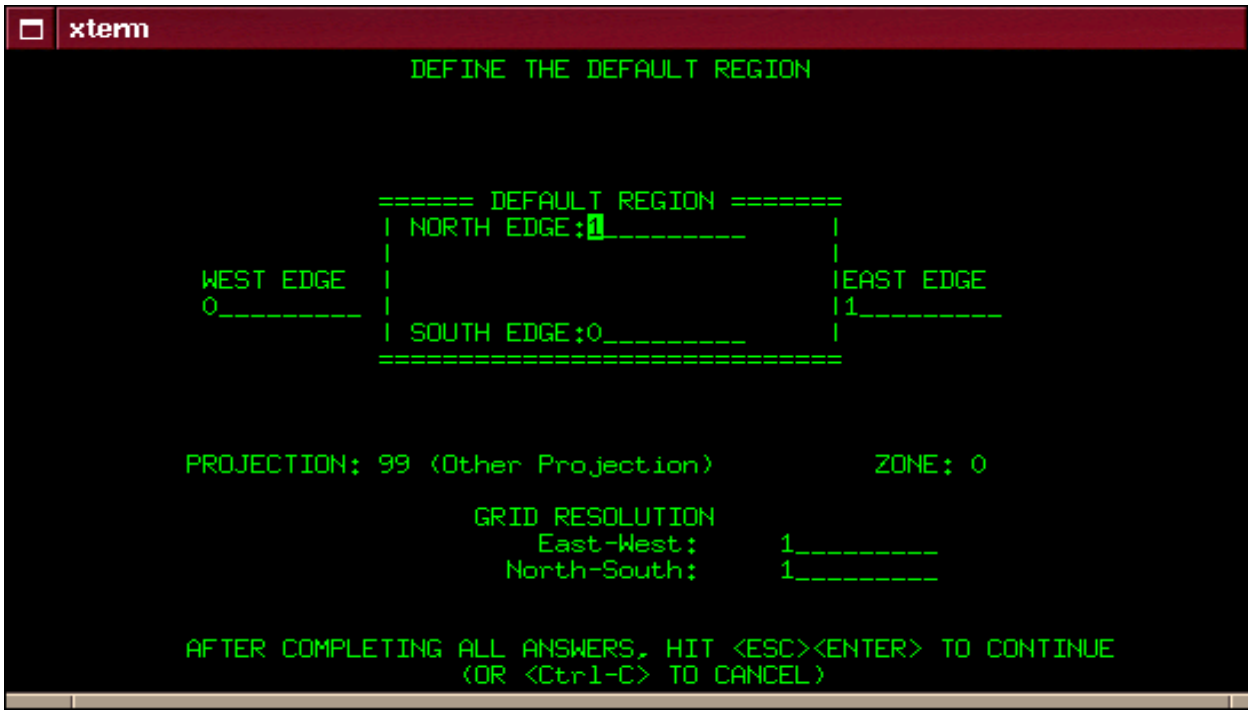
Now, you need to attribute different parameters to the location, such as the coordinate system you want to use, including the ellipsoid, the coordinates of the boundaries of the project area and the default resolution for raster data:

- Start out by chosing between, x,y, Latitude-Longitude, UTM or another coordinate system. This choice depends on your data and the use will make of it.
- Now one line describing the project area, for example "Topo Map of the Alps"

Now some more information about the projection follows. Note that the prompts vary from projection to projection:

- (if you chose "D - Other Projection") "specify projection name": "list" gives you the list of all available projections, examples are "tmerc" for Transverse Mercator, "lcc" for Lambert Conformal Conic, "moll" for Mollweide, etc.
- specify ellipsoid name}: again use "list" to get a list of available ellipsoids, examples are "sphere", "clark80", "wgs84", etc.
- if you want, you can specify a datum, again use "list" for available options
- Enter Central Parallel: 0 if you want the Equator as the central parallel
- Enter Central Meridian: 0 if you want the Greenwich meridian as central meridian
- Enter Scale Factor at the Central Meridian}
- Enter False Easting
- Enter plural form of units: for example, meters

Next is the description of the boundary coordinates of the project area and the definition of the default raster resolution:



The default raster resolution (GRID RESOLUTION) has to be chosen according to the needs. Generally, it is advisable to work in steps of 0.25 (0.25, 0.5, 1.75, 2.00, 12.25 etc.). This resolution does not concern vector and site data since these are stored with their exact coordinate values. Note that every raster map may have its own resolution. You can leave this screen with “ESC”-“RETURN” and then accept the list of parameters that appears, if everything is correct.

You will get back to the startup screen again to enter the mapset’s name (if not already entered). Another “ESC”-“RETURN” will finally let you leave this screen. This mapset is created within the new location by answering “yes” to the next question. The mapset will use the parameters of the location (such as the region and resolution definitions) as its default parameters.

Now the project area, i.e. the location including a mapset has been created. You have "arrived" in the GRASS system and can start working within this new location.

Notes

1. http://grass.itc.it/gdp/html_grass5/projections.html

Chapter 17. Manage your data

Different commands allow you to list, copy, rename or erase data within the current location..

- g.list[1]: Lists available GRASS data base files of the user-specified data type to standard output.
- g.rename[2]: Renames data base element files in the user's current mapset.
- g.copy[3]: 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.remove[4]: Removes data base element files from the user's current mapset.

If you wish to deal with an entire location you will have to do so by hand, *after having left GRASS*.

- In order to remove a location with the name "location_name", go to the directory that contains this location (i.e. the GRASS database directory) and use the command **rm -rf location_name**. This will *irrevocably* erase all the data, so be careful !
- In order to copy a location with the name "location_name" to another directory or another machine, go to the GRASS database directory and use the command **tar cvf location_name.tar location_name** to package the entire directory into one file. You should then compress this file with **gzip location_name.tar** or **bzip2 location_name.tar**. Copy the resulting file to the new location. Be aware, however that user and group settings (gid and uid) might get mangled, so be prepared to change those with **chown**.

In order to access maps within the same location, but in another mapset, you have to set your mapset search path. If you do not wish some of your data to be accessible for everyone, you can limit the access to a particular mapset you own.

- g.mapsets[5]: 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.access[6]: Control access to the current mapset.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/g.list.html
2. http://grass.itc.it/gdp/html_grass5/html/g.rename.html
3. http://grass.itc.it/gdp/html_grass5/html/g.copy.html
4. http://grass.itc.it/gdp/html_grass5/html/g.remove.html
5. http://grass.itc.it/gdp/html_grass5/html/g.mapsets.html
6. http://grass.itc.it/gdp/html_grass5/html/g.access.html

Chapter 18. Supported formats

Import modules[1]

Export modules[2]

Notes

1. http://grass.itc.it/gdp/html_grass5/import.html
2. http://grass.itc.it/gdp/html_grass5/export.html

Chapter 19. Raster Import

The module r.in.gdal[1] offers a common interface for many different raster formats[2]. Try this first, especially since it also offers such practical options as on-the-fly location creation or extension of the default region in order to adapt it to the imported file.

If r.in.gdal does not suit your needs, use the appropriate r.in.* module[3] (replace the * with the name of the format you wish to import).

After the import, you will probably want to run r.support[4] in order to modify or create the GRASS support files.

For importing scanned maps, you will need to create a x,y-location according to the instructions in Chapter 15, scan the map in the desired resolution and save it into an appropriate raster format (e.g. tiff, jpeg, png, pbm) and then use r.in.gdal to import it. You will probably have to recify it in order to obtain geocoded data. Chapter 28 contains more information about this process.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.in.gdal.html
2. http://www.remotesensing.org/gdal/formats_list.html
3. http://grass.itc.it/gdp/html_grass5/raster.html
4. http://grass.itc.it/gdp/html_grass5/html/r.support.html

Chapter 20. Vector Import

For vector import use the appropriate v.in.* module[1] (replace the * with the name of the format you wish to import). There is no common interface for different formats (yet).

After the import, you have to run v.support[2] in order to build the relevant GRASS support files. Some of the vector import modules run this automatically for you, so check the relevant man page.

Notes

1. http://grass.itc.it/gdp/html_grass5/vector.html
2. http://grass.itc.it/gdp/html_grass5/html/v.support.html

Chapter 21. Sites (point data) import

The easiest way to profit from the new multi-dimension and multi-attribute site format in GRASS 5.0 is to create the file yourself. You can find details about the format in the s.in.ascii[1] man page. Once you have created the file, you can "import" it into GRASS by copying it directly into your mapset: **cp NameOfYourSitesFile $GISDBASE/$LOCATION_NAME/$MAPSET/site_lists/** (you have to be in a running GRASS session for this command to work).

For site import from other formats use the appropriate s.in.* module[2] (replace the * with the name of the format you wish to import).

Notes

1. http://grass.itc.it/gdp/html_grass5/html/s.in.ascii.html
2. http://grass.itc.it/gdp/html_grass5/sites.html

Chapter 22. Managing GRASS Monitors

GRASS map display windows are no “normal” windows. Rather, they display geographical data with coordinates. These windows are called "monitors" in GRASS and are managed with the d.mon[1] command or through the Display->Monitors menu in TclTkGRASS.

You can open several different monitors at once. Use **d.mon start=** to start the monitor of your choice and **d.mon select=** to select the monitor you want to display data on next. To stop a monitor, use **d.mon stop=** or simply click on the closing button provided by your window manager. You can also resize a monitor the way you would resize any window in your window manager.

Frames in monitors

GRASS offers the possibility to divide a monitor into several distinct frames. This gives you the opportunity to create a more sophisticated layout of your maps and other data. For example, you can create a frame for header information (title, date, etc), a frame for the actual map, a frame for footer information (author, sources, etc), a frame for the legend, etc, etc. The module for frame creation is d.frame[2] and it is quite simple to use (see the manual page for details):

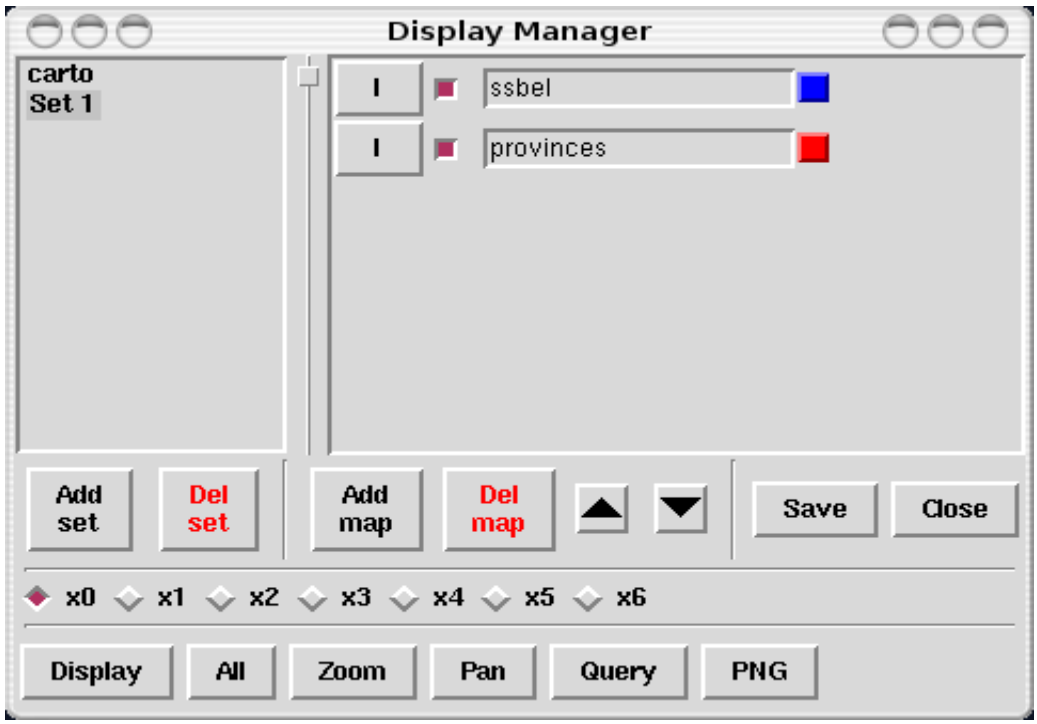
```
d.frame -c frame=title at=90,100,0,100 # create a title frame
echo "TITRE" | d.text -b size=75 at=45,30 # write the title into the title frame
d.frame -c frame=map at=10,90,0,100 # create a map frame
d.rast combel # draw a raster map into that frame
d.vect autoroute col=violet # draw a vector map into the same frame
d.frame -c frame=legend at=0,10,0,100 # create a legend frame
echo "Cartography: M. Lennert" | d.text size=20 at=75,50 # draw text in the legend fram
d.barscale at=10,920 # create a barscale in the legend frame
```

Notes

1. http://grass.itc.it/gdp/html_grass5/html/d.mon.html
2. http://grass.itc.it/gdp/html_grass5/html/d.frame.html

Chapter 23. Displaying Maps

You might want to begin with the gui display manager, d.dm[1], which facilitates the choice and display of maps, and thus makes life easier for those not too comfortable with the individual commands.



Other than that, maps can be displayed with the d.* display commands[2] (for which **d.dm** is just a frontend), such as:

- d.rast[3]
- d.vect[4]
- d.sites[5]
- d.vect.area[6] for filled vector areas
- d.rgb[7] to combine three raster map layers (with a grey-scale color map) to form a color (Red, Green, Blue) image

Colors

GRASS offers two ways of chosing colors, either by using the standard color names (red, orange, yellow, green, blue, indigo, white, black, brown, magenta, aqua, gray, grey) or by indicating R:G:B triplets (values between 0 and 255 of red, green and blue), thus allowing TrueColor support. (NOTE: In GRASS 5.0 TrueColor support is available for some display commands only. From version 5.3 on it is available in almost all the core display modules.)

Scripting the display of maps (and frames)

When you have to repeat all the commands above, it is easier to have them in a script file instead of retyping them every time. You can create such a script file yourself in any text editor, but GRASS also offers you the possibility to use d.save[8] to write the commands that led to the current monitor content into a script file. This allows you to test a layout on your screen command by command, and then, once you are satisfied,

to save this layout into a file. This is especially useful for cartography (see Part XIII in *Grass Tutorial*).

Notes

1. http://grass.itc.it/gdp/html_grass5/html/d.dm.html
2. http://grass.itc.it/gdp/html_grass5/display.html
3. http://grass.itc.it/gdp/html_grass5/html/d.rast.html
4. http://grass.itc.it/gdp/html_grass5/html/d.vect.html
5. http://grass.itc.it/gdp/html_grass5/html/d.sites.html
6. http://grass.itc.it/gdp/html_grass5/html/d.vect.area.html
7. http://grass.itc.it/gdp/html_grass5/html/d.rgb.html
8. http://grass.itc.it/gdp/html_grass5/html/d.save.html

Chapter 24. Zooming and Panning

Use d.zoom[1] for zooming and panning in the currently selected monitor. **d.zoom** without any command line options allows you to zoom in by selecting a zooming frame (left mouse button) or to zoom out (middle mouse button). If you launch **d.zoom -f**, you get the option between zooming (left mouse button) or panning (middle mouse button). If you only want to pan, try d.pan[2].

Both **d.zoom** and **d.pan** change your current region settings. They are, in that sense, an interactive version of g.region[3], so be aware that any command using the current region settings will be affected by the use of **d.zoom** or **d.pan**.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/d.zoom.html
2. http://grass.itc.it/gdp/html_grass5/html/d.pan.html
3. http://grass.itc.it/gdp/html_grass5/html/g.region.html

Chapter 25. Adding Legends and Scales

Legends in GRASS only exist for raster maps. Currently, GRASS does not support legends for vector maps such as those drawn with d.vect.area[1].

See the module d.legend[2] for your legends. (This module is in active development for the moment, so its usability should continue to be enhanced in the near future.) You can use **d.legend** to display a legend in the same monitor as the map, or in a different monitor (use d.mon[3] to start and/or select a different monitor). Through its "-m" option **d.legend** allows you to place and size the legend with the mouse.

Currently d.barscale[4] is your best choice for placing a barscale on your map, including a small north arrow. If you would prefer a simple line instead of a barscale, you can use d.scale[5] (NOTE: this is depreciated as of GRASS 5.3, **d.barscale -l** does the same thing, only better). However, the latter does not survive a zoom or pan, while the former does. Furthermore, **d.barscale** also gives you the choice of feet/miles instead of meters.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/d.vect.area.html
2. http://grass.itc.it/gdp/html_grass5/html/d.legend.html
3. http://grass.itc.it/gdp/html_grass5/html/d.mon.html
4. http://grass.itc.it/gdp/html_grass5/html/d.barscale.html
5. http://grass.itc.it/gdp/html_grass5/html/d.scale.html

Chapter 26. Visualize in 3D with nviz

For a tutorial on the use of nviz, the 3D visualization program for GRASS, see here[1]. For some examples of what can be done with nviz, see here[2].

Notes

1. http://grass.itc.it/gdp/nviz/nviz_tut.html
2. http://grass.itc.it/gdp/nviz/index.html

Chapter 27. Digitizing Vector Maps

There are two ways of vectorizing maps (AKA digitizing):

- using a digitizer,
- digitizing on-screen.

In the first case the map is placed on the digitizer, the corners are selected by a mouse click and the respective coordinates entered through the keyboard. This process is called "'registering a map"'. The advantage of this method is that the user is always in control of the whole map. However, the high price of the equipment and the lack of magnification capabilities, e.g. for low-quality maps, are significant disadvantages. Furthermore, the map must not show any signs of lateral stretch to prevent wrong site coordinates.

On-screen digitizing requires a scanned and geocoded raster map (image) that is displayed on a GRASS monitor. All relevant map objects will be vectorized using the mouse. It is not necessary to register such a map as it is geocoded already. The advantage of this method is the support of zooming, hence an improved accuracy can be achieved. Apart from access to a scanner no financial input is required. However, the disadvantage of this method lies in the somewhat awkward orientation on the map on the screen.

Rules for Digitizing in Topological GIS

There are a few basic rules regarding digitizing from analogue maps that apply to topological GIS, such as GRASS. Obedience to these rules is essential in order to use the topological features of the software.

- Lines must not cross without nodes.
- Lines that use common "node" must hit it exactly. Make use of the snapping function of the digitizing module.
- Common area boundaries must only be digitized once.
- Areas must be closed. Use the snapping function of the digitizing module.
- Store lines and areas in separate maps to avoid problems with crossing lines. It is also easier to assign a certain type (line or area boundary) to a line.

There should not be any problems when all the rules are fulfilled.

Digitizing Maps

If there is no digitizer available but a scanner, it is still easy to digitize a map. You can find information on importing a scanned map into GRASS in Chapter 19 and Chapter 28.

You can use your mouse for digitizing instead of a digitizer. After starting a GRASS monitor, run the module v.digit[1] (in tcltkgrass chose 'Vector->Develop map->Digitize')to change the settings from digitizer to mouse. Choose digitizer "'none"'. After selecting a new or existing vector file you will see a dialogue requesting project data. It is necessary to change the parameter "'Map's scale"' from 1:0 to the respective scale of the map:

```
Provide the following information:

        Your organization    Geographisches Institut_____
        Todays date (mon,yr) Jan 25 99__________
        Your name            Emil_______________
        Maps name           realnutzung_____________________________
```

```
Maps date           __________
Maps scale          1:25000____
Other info           Sommer 1998_____________________________
Zone                 0____
West edge of area    3568750_______
South edge of area   5762774_______
East edge of area    3574250_______
North edge of area   5767726_______
```

After completing this dialogue you will be transferred to the main menu.

In order to digitize on the basis of the scanned raster map, place it in the background: Choose "Backdrop cell map" ('B') from the "Customize" menu ('C'). This will load the raster map to the background.

Now you can open the digitizing menu by pressing 'D'. The module v.digit[2] is somewhat self-explanatory, for more specific information please refer to the CERL v.digit tutorial (pdf file)[3]. The 'Color' menu under 'Customize' allows you to change the colors of the digitized objects (lines, areas). This allows for optimized color coding. It is important to choose the appropriate type of object (area, line, site) by pressing 't'. If necessary, switch on the 'auto labelling function'. This function assigns the category number, however, it is not (yet) possible to enter the category text in v.digit. Because of this you should write down which category number belongs to which object. Run the module v.support[4] to enter the category labels ('Edit the category file'- in tcltkgrass chose 'Vector->Develop map->Edit vector categories').

Make use of the 'zoom function to improve your accuracy significantly.

To avoid confusion: Points may be saved as vectors or in GRASS sites format. Vectors are usually the result of digitizing, points in the GRASS format result from files with coordinates (N,E) and attributes.

Again, it is an important rule to digitize boundaries of adjacent areas only once. GRASS automatically assigns this boundary to both areas. Never digitize two parallel lines!

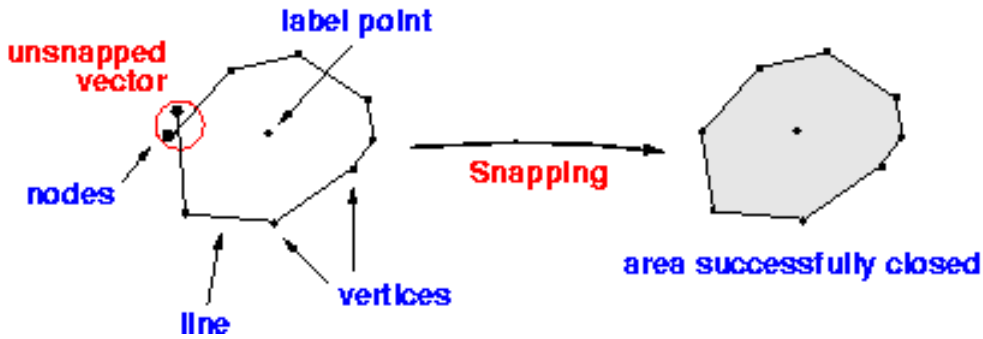
Digitizing Areas

Digitizing areas is generally a bit harder and requires more practice. For this reason we will explain setting of attributes in more detail. Choose the vector types in the 'Digitize' menu of the v.digit module.

Press 't' to toggle the type between:

- LINE,
- AREA EDGE,
- SITE.

It is mandatory to close areas because only then you can create the GIS vector topology and assign label points. Since it is nearly impossible to hit line ends exactly, the **snapping** function allows the closing of areas:



Under 'Customize', in the main menu of v.digit, you can adjust the snapping threshold, **'s' - Set snapping threshold**. After setting it to a reasonable value the nodes will automatically snap to close the area. Only after connecting all nodes your area will be recognized as such. The snapping threshold should be chosen appropriately for the scale of the map. You have to enter the value in inches, but it will be automatically converted to the metric units of the map.

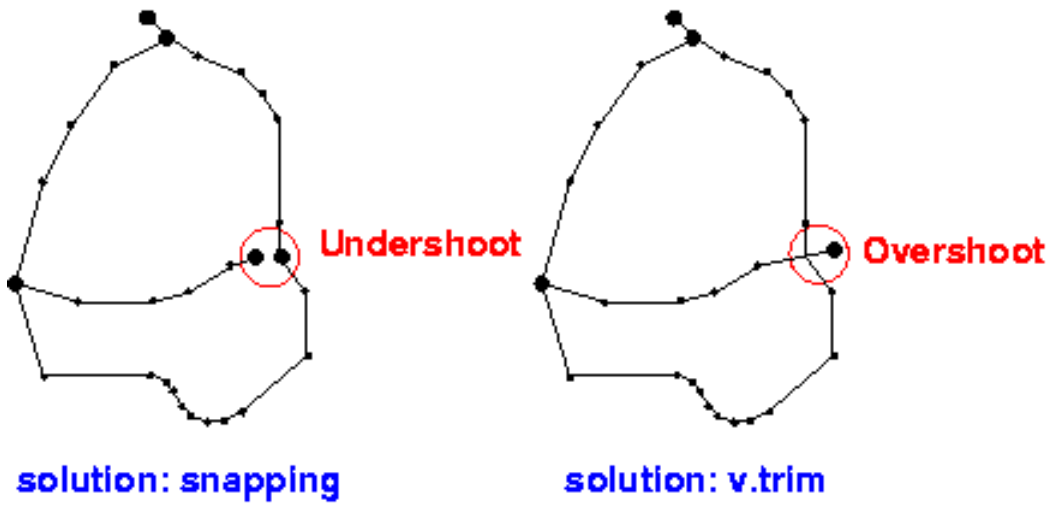
Here are some examples:

- For 1:5.000 - 1:10.000: Snap distance 1-2m (Value in Inches in the menu: 0.0017 to 0.002)
- For 1:10.000 - 1:25.000: Snap distance 2-5m (Value in Inches in the menu: 0.002 to 0.008)
- For 1:25.000 - 1:50.000: Snap distance 5-10m (Value in Inches in the menu: 0.008 to 0.017)

Note: GRASS will not display a useful value in the menu if you did not enter the correct scale at the very beginning. In this case exit v.digit and restart it with the same map. Now set the correct scale in the first dialogue.

Here are some of the more common problems with digitization:

Lines may not connect properly when either the snapping threshold was set inappropriately or the zoom factor was too small. Too short lines are called 'undershoot', too long ones 'overshoot'.



Use the snapping function to link the vectors in the case of undershoot. 'Snapping' is a function of v.digit and v.support (enter the snapping threshold in accordance to the map scale). Run the GRASS module v.rm.dangles[5] to trim 'overshoots'.

Note: Some people use 'overshoots' deliberately to make sure areas are closed. However, it is necessary to trim these lines afterwards. It is common use to create a square

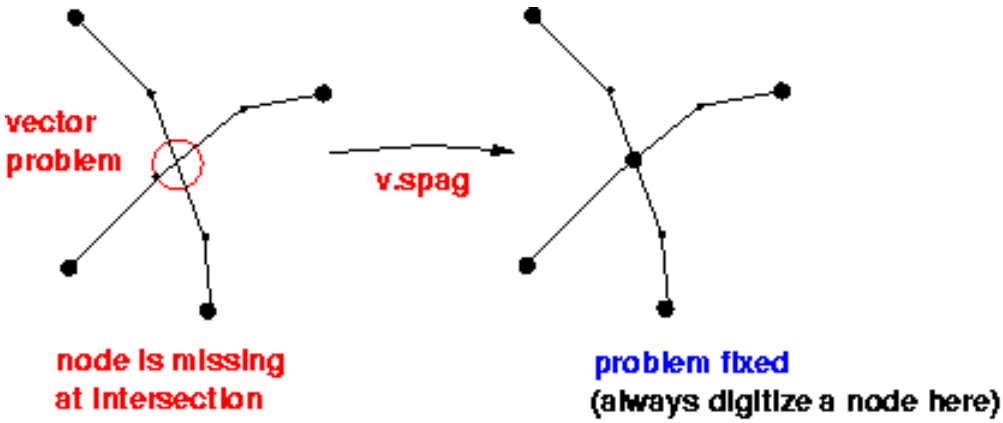
- 'neatline' - around the project area. With this method you can vectorize your map and 'overshoot deliberately as GRASS can trim automatically to the boundaries of the square at a later stage. The square is considered part of the area boundary.

As a general rule, always run v.support[6] (in tcltkgrass: 'Vector->Develop map->Create/rebuild topology') after v.digit to (re-)create the topology of the vector data. At this point you may also want to enter the appropriate category texts ('Edit the category file'). If you have got a lot of category numbers there is the option to enter line numbers in the bottom line of the window, press 'ESC 'RETURN to get there.

Post-digitizing work:

Often it proves to be quite difficult to match up the end points of lines when vectorizing areas. (An area is a closed polygon, which means both ends of the line have to be connected). The v.spag[7] module can help if you encounter such problems.

Another very useful feature of **v.spag** is inserting missing nodes at line intersections. However, use this command with care! Create a backup copy of your map with g.copy[8] to be on the safe side. You cannot undo changes made with v.spag!



Other very helpful modules are v.clean[9] and v.prune[10]. Use **v.clean** to remove 'dead' lines from your map. 'Dead' lines are vectors that have been marked as deleted in v.digit. The module **v.prune** can be used to remove obsolete nodes. Use it with care as you can simplify complex areas/polygons to squares or triangles if you remove too many nodes.

Digitizing of Elevation Isolines

Digitizing isolines works just like with ordinary vector lines. GRASS offers an easy way to attach the elevation data to these lines:

First digitize the lines without attributes. Then change to the 'Label' menu by pressing 'L'. Now hit 'i' for 'contour interval' and select the appropriate interval of lines, default is 5 base units per line. The base unit is usually meter, hence it defaults to 5 m. After that press 'c' for 'Label contours' and start entering your elevation data. Generally, if you assign elevation attributes to the outer and inner isolines, all the lines in between will be assigned automatically depending on the given interval. To get this to work you need to draw a line between the first and the second point of your choice. All the isolines that this line crosses receive an attribute containing their elevation. GRASS automatically checks if the number of lines matches the chosen interval. Take care not to get too close to isolines you don't want to label, as the temporary line allows some tolerance in placement. If necessary change the thresholds in the 'Customize' menu (press 'C').

Select an outer line with the left mouse button, e.g. in a 'valley, and confirm your selection with the middle mouse button. Now enter the elevation of this line. Then point the mouse to the other side of the lot of lines, e.g. on a 'hill, and again select with

the left mouse button, confirm with the middle one and enter its elevation. Now these two lines are connected by a straight line that crosses all the isolines in between. All these lines automatically get assigned the appropriate value. In the case the chosen interval and the number of lines do not match GRASS will display an error (warning) message and stop the process. If this happens please count again or choose smaller steps.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/v.digit.html
2. http://grass.itc.it/gdp/html_grass5/html/v.digit.html
3. http://grass.itc.it/gdp/vector/digit.pdf
4. http://grass.itc.it/gdp/html_grass5/html/v.support.html
5. http://grass.itc.it/gdp/html_grass5/html/v.rm.dangles.html
6. http://grass.itc.it/gdp/html_grass5/html/v.support.html
7. http://grass.itc.it/gdp/html_grass5/html/v.spag.html
8. http://grass.itc.it/gdp/html_grass5/html/g.copy.html
9. http://grass.itc.it/gdp/html_grass5/html/v.clean.html
10. http://grass.itc.it/gdp/html_grass5/html/v.prune.html

Chapter 28. Processing Scanned Maps

In order to process a scanned map, you first have to import it, probably with r.in.gdal[1], into an x,y-location, prepared according to the calculations in Chapter 15. Then you can rectify it in order to obtain geocoded data.

Don't forget to use g.region[2] to make sure your map is correctly displayed and treated: **g.region rast=NameOfYourRasterMap**.

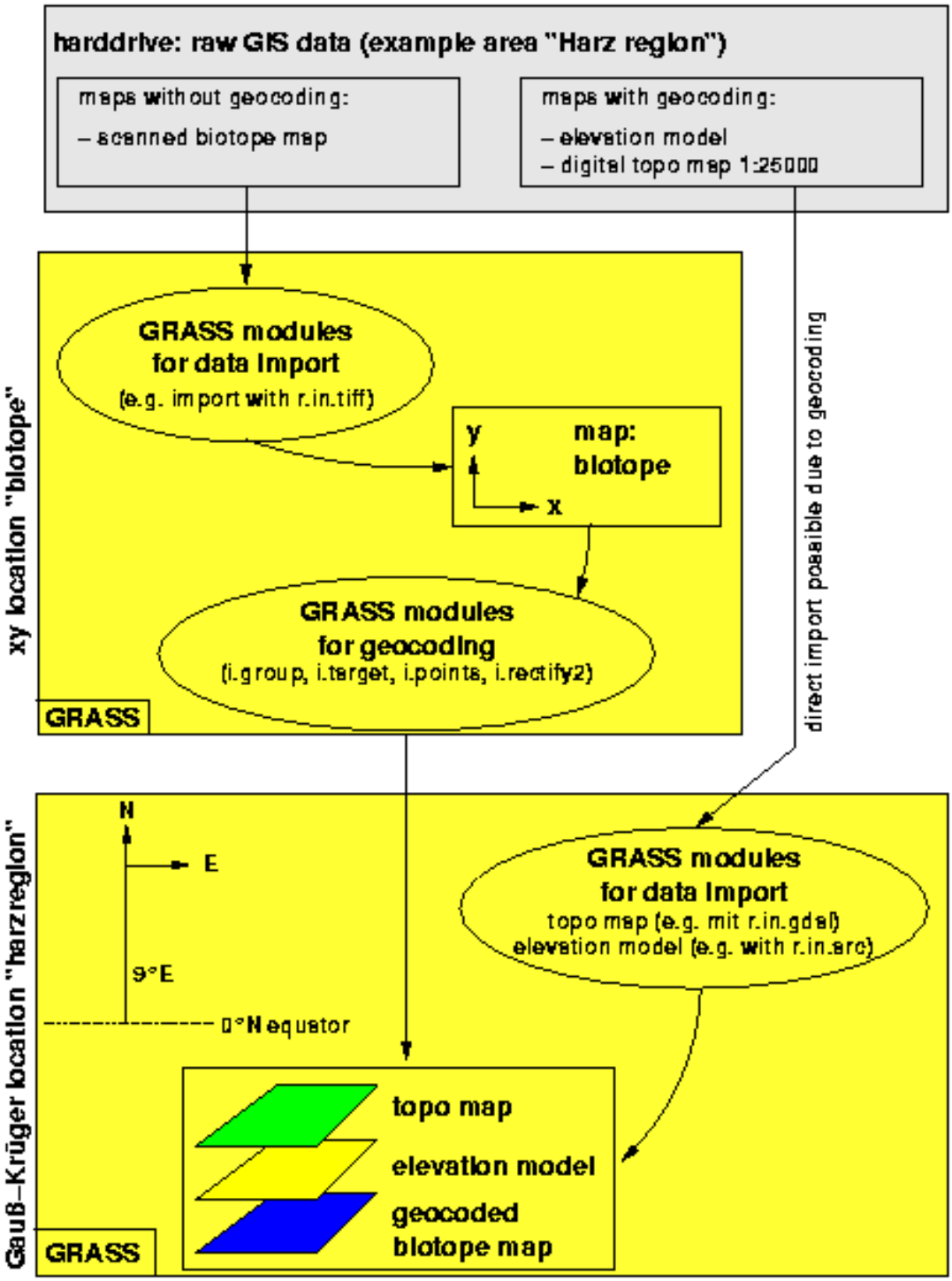
In this section the rectification of a scanned map to its topographic reference will be explained. For better understanding you should read the Section called *General definition of a project area when using scanned maps* in Chapter 15.

Commonly such files are stored in TIFF, PNG or other formats. The amount of rows and columns can be set in the scanning software used, or obtained through the `ImageMagick` **identify** command.

Start GRASS with an xy location which has been set up according to the size of the scanned map, and import it as described earlier. The scanned map will now be transformed by an affine transformation (with the i.rectify[3] module[4] The affine transformation rotates, stretches and contracts, and is usable for raster data, for which the internal orientation should be kept.

Geocoding of scanned maps

Now the "rectification" of the raw map, i.e. its transformation for geocoding, will be performed. The process explained here is valid for scanned, unreferenced data only. We will use the modules i.rectify[5], i.points[6], and i.target[7] modules.



If you have digital, already geocoded data and want to change the projection, please refer to m.proj[8] and r.proj[9] for automated map transformation.

After importing the map, the process is as follows: The map has to be added to a so called "image group". This is simply a list of raster data files to be processed, all images should have the same geocoding. Subsequently a transformation target is committed, which is an additional location . For example a UTM location. Now the geographic references have to be set to "tell" the transformation module about the new coordinates for every pixel in the new UTM location. Therefore the four corner

coordinates in the xy location are assigned geographical coordinates. These are, of course, the geographical corners, not map sheet paper corners! If there are no readable map borders present, e.g. you have scanned only a cut of the map, you can use the corner points of printed reference crosses. These should be chosen as close as possible towards the "real" corners of the map. These points have to enclose a rectangular area, as the cut will be turned, stretched and contracted in the following affine transformation.

If no reference crosses are available either, use well identifiable features, such as road intersections. Once the geographic references are assigned, the transformation of the raw map into the UTM location is performed. The process in detail is as follows:

a. Prompt the name of the newly to be set up image group: **$ i.group**
   - Name this group, for example: "map1".
   - Mark the map to be imported with a "x".
   - Leave module i.group with "return".

b. Indicate the target location and mapset (into which the UTM location should be transformed) in: **$ i.target**

c. Start a GRASS monitor: **$ d.mon x0**

d. Assign the UTM coordinates to the four corner points of the image to be transformed: **$ i.points**
   - Prompt the image group to be transformed (contains only the map), in this example "map1".
   - Change to the GRASS monitor. Here display the imported map.
   - Using the mouse, select as precisely as possible the first reference cross (first corner point of the image to be transformed). Enter the related UTM coordinate at the command line (the related easting and northing, as taken from the printed map), delimited by blanks. The "ZOOM" function is quite useful for this, allowing to find the matching points more easily.

     With help of the "Analyze" component you can check the "rms error".[10] It should not be higher than the GRID RESOLUTION of the UTM-location. All partial errors (one for every matching point) are added up into an over all error. Is this one to large, you can adjust it with resetting and reassigning of single matching points. In the "Analyzes" window double click the point concerned for to delete it. Afterwards reassign it to reduce the "rms error". Are all four points assigned sufficiently correct, leave $ i.points , all assignations will be saved automatically.

e. Now start the transformation module: **$i.rectify** with a 1st grade polynom (as "order of transformation""). This will perform the linear transformation.

   First the image group to be transformed (in this case: "map1") and the name of the new file(s) are prompted. Now choose "1" as the "order of transformation". Finally you will be asked if you want to transform into

   a. the current location or

   b. the "minimal region".

   Here you must choose menu point (1.), which is equivalent to the complete UTM location . Otherwise only the current active part of the UTM location would be transformed, which could be a cut of the complete area.

The computation time for an A4 size map (21x29,7cm) scanned with 300dpi is on a SUN SPARC/25 close to five minutes. A Linux PC (above 200MHz) works faster.

As UNIX is capable of multitasking, you can go on working with GRASS, or even leave it, while the computation runs in the background. After the transformation has finished (i.rectify sends an email then), the success should be checked in the target-location (if you did not do it yet, leave and restart GRASS now: exit the xy location and start it again in the UTM location). After starting a GRASS monitor the transformed map can be displayed with d.rast[11].

The d.what.rast[12] module allows in combination with the magnification of single map areas (see Chapter 24), to check the coordinates of the reference crosses. These should, of course, correlate with the equivalent ones on the printed map. Otherwise the "rms error" was probably too high. Correcting is possible by reassigning single points in the xy location. In this case the transformed map in the UTM location should be deleted (with r.remove[13]), as it will be remade in the new transformation. Subsequently transform with i.rectify[14] as described above. The result should, again, be checked. If the transformation was successfull, then the xy location, which is now not needed anymore, can be deleted (see Chapter 17 for how to do this).

Gap free geocoding of multiple, adjacent, scanned maps

The transformation described in the preceding section can be used for importing several adjacent scanned maps without gaps. Access to drum scanners will exist only in rare cases, but normal maps are to large for customary scanners.

A usable solution is the scanning of maps in multiple parts. This solution requires some more expense, but spares the purchase of an expensive scanner (large scale scanner). It is very important to scan with overlapping borders, as this will improve the fixing of matching points.

As described above, a target location has to be set up in the target coordinate system, large enough to cover the complete area to be scanned. The resolution should be chosen sufficiently high to display the smallest conventional sign.

All scanned raw maps are imported into the xy location subsequently. Please pay attention to the fact, that the extent of the xy location has to be equal to the extent of the complete area to be scanned.

Now open an image group for every imported map (even if it contains only one map), and adjust the transformation target for all of them to the UTM location (modules i.group[15] and i.target[16]). The following process:

Each of the four corner coordinates of the raw maps to be transformed is assigned a UTM coordinate pair (i.points[17]), see preceding section). These points must surround a rectangular area, as this area will be turned and resized with the affine transformation. With i.rectify[18] (as 1st grade polynom) the according map will be transformed into the UTM system.

Do the same with all the other maps in the xy location.

Once all scanned maps are transformed, the result can be checked in the UTM location (for that you will have to leave the xy location). Restart GRASS and choose the UTM project area. Now all individual maps should be checked for their correct positioning and orientation (base accuracy). Open a GRASS monitor and put the region to maximum (default value): g.region -d[19]

Afterwards it is absolutely necessary to run d.erase[20], to inform the graphical subsystem of the changed coordinates. With starting d.rast[21] without parameter (interactive mode) you have the possibility (after choosing the file to display) to overlay raster images (overlay mode: "yes" or flag "-o"). This way each file gets displayed after each other, and the maps should lie next to each other. With d.zoom[22] you can now inspect

if there are any gaps between the maps (redisplaying with d.rast is necessary). Ideally there are no gaps to be seen.

If the maps show any unwanted borders, these can easily removed. To do so, zoomed into the map with d.zoom[23] and adjust the new coordinates with g.region[24] in small steps to reach "comfortable", rounded values. Here you can also use the "-a" flag in combination with "res=" parameter of g.region[25] to align the map boundaries with respect to the desired resolution. In order to save the map at the new size, generate a "self copy" of the displayed map portion with r.mapcalc[26]:

mapcalc> new_map = old_map

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.in.gdal.html
2. http://grass.itc.it/gdp/html_grass5/html/g.region.html
3. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
4. The affine transformation is a linear transformation, the parameters of which are calculated through regression analysis. The "nearest neighbor resampling" method is used by i.rectify during the transformation.
5. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
6. http://grass.itc.it/gdp/html_grass5/html/i.points.html
7. http://grass.itc.it/gdp/html_grass5/html/i.target.html
8. http://grass.itc.it/gdp/html_grass5/html/m.proj.html
9. http://grass.itc.it/gdp/html_grass5/html/r.proj.html
10. The "rms error" represents the distance of the matching point from ideally placed matching point. It is calculated through: rms = ((x-x orig)^2 + (y-y orig))^(1/2)
11. http://grass.itc.it/gdp/html_grass5/html/r.rast.html
12. http://grass.itc.it/gdp/html_grass5/html/d.what.rast.html
13. http://grass.itc.it/gdp/html_grass5/html/g.remove.html
14. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
15. http://grass.itc.it/gdp/html_grass5/html/i.group.html
16. http://grass.itc.it/gdp/html_grass5/html/i.target.html
17. http://grass.itc.it/gdp/html_grass5/html/i.points.html
18. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
19. http://grass.itc.it/gdp/html_grass5/html/g.region.html
20. http://grass.itc.it/gdp/html_grass5/html/d.erase.html
21. http://grass.itc.it/gdp/html_grass5/html/d.rast.html
22. http://grass.itc.it/gdp/html_grass5/html/d.zoom.html
23. http://grass.itc.it/gdp/html_grass5/html/d.zoom.html
24. http://grass.itc.it/gdp/html_grass5/html/g.region.html
25. http://grass.itc.it/gdp/html_grass5/html/g.region.html
26. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html

Chapter 29. Raster Categories and Attributes

In the raster data model, cell category numbers can be one of two things: either they are measurements of real-life surface values (light intensity in images, height in digital terrain models, slope, temperature, etc) or they represent classes of categories (scanned maps, land use, soil types, etc). In the first case, labels are not very necessary since the type of map defines the type of values themselves, in the second, they are indispensable in order to document the meaning of the category numbers.

In GRASS, the raster map is stored in a binary file which contains the category numbers for each cell. The category labels are stored in a text file which contains the category numbers with their respective labels. This chapter will look at different aspects of the management of categories.

Viewing category values

The first thing you might wish to do is see which category values are present in your raster file. Here is a list of modules you can use for this purpose:

- r.cats[1] : Prints category values and labels associated with user-specified raster map layers
- r.describe[2] : Prints terse list of category values found in a raster map layer
- r.what[3] : Queries raster map layers on their category values and category labels
- d.what.rast[4] : Allows the user to interactively (with the mouse) query the category contents of multiple raster map layers at user-specified locations within the current geographic region
- r.report[5] : Reports statistics for raster map layers, by category
- r.stats[6] : Generates area statistics for raster map layers (similar to r.report
- r.statistics[7] : Category or object oriented statistics
- r.univar[8] : Univariate statistics for a GRASS raster map

For more information on statistics and reports, see Chapter 33.

Changing category values

You have to distinguish between changing the category values of a map and changing the category labels. Actually the first is not really possible without creating a new map, dropping the old one and renaming the new one to the old one's name. You can do the latter directly on a map.

In order to create a new map by changing the category values of an already existing one, you can use the following modules:

- r.reclass[9] : Creates a new (pseudo-)map layer whose category values are based upon the user's reclassification of categories in an existing raster map layer
- r.recode[10] : Creates an output map layer based on an input raster map layer
- r.rescale[11] : Rescales the range of category values in a raster map layer (also see r.rescale.eq[12] and r.rescale.inf[13]
- r.mapcalc[14] : Raster map layer data calculator (see Chapter 36 for more detailed information)
- r.clump[15] : Recategorizes data in a raster map layer by grouping cells that form physically discrete areas into unique categories

For changing the category labels of a raster map, use r.support[16]. Enter 'y' when you get to the question "Edit the category file for [mapname]?". You will get to a screen

showing the highest category number. You normally don't want to change that, so just go on by typing **ESC-RETURN** to enter the category table 'editor'. To go on to the next screen of the editor, type **ESC-RETURN** again. To finish, just type 'end' at the "Next category" prompt.

You might wish to automate the assigning of labels. Here's an example of how you could use **r.stats** and **r.reclass** to assign the total area size in square meters of each category to each cell of that respective category: **r.stats -qan in=map | awk '{printf "%d=%d %d sq meters\n", $1, $1, $2}' | r.reclass in=map out=newmap**[17]

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.cats.html
2. http://grass.itc.it/gdp/html_grass5/html/r.describe.html
3. http://grass.itc.it/gdp/html_grass5/html/r.what.html
4. http://grass.itc.it/gdp/html_grass5/html/d.what.rast.html
5. http://grass.itc.it/gdp/html_grass5/html/r.report.html
6. http://grass.itc.it/gdp/html_grass5/html/r.stats.html
7. http://grass.itc.it/gdp/html_grass5/html/r.statistics.html
8. http://grass.itc.it/gdp/html_grass5/html/r.univar.html
9. http://grass.itc.it/gdp/html_grass5/html/r.reclass.html
10. http://grass.itc.it/gdp/html_grass5/html/r.recode.html
11. http://grass.itc.it/gdp/html_grass5/html/r.rescale.html
12. http://grass.itc.it/gdp/html_grass5/html/r.rescale.eq.html
13. http://grass.itc.it/gdp/html_grass5/html/r.rescale.inf.html
14. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html
15. http://grass.itc.it/gdp/html_grass5/html/r.clump.html
16. http://grass.itc.it/gdp/html_grass5/html/r.support.html
17. This example was taken from M. Neteler, H. Mitasova, 2002.

    18. http://mpa.itc.it/grassbook/
    , p. 84.
18. http://mpa.itc.it/grassbook/

Chapter 30. Vector Categories and Attributes

Viewing category values

To see information about the category values and labels of your vector file use:

- v.report[1] : Generates statistics for vector files
- v.what[2] : Query the category contents of a (binary) vector map layer at user-selected locations

Changing category values

As with raster maps you have to distinguish between changing an existing map's categories and creating a new map out of the categories of an old one. Contrary to raster maps, you can change the category numbers of existing vector maps:

- v.digit[3] : A menu-driven, highly interactive map development program used for vector digitizing, editing, labeling and converting vector data to raster format (the universal tool for altering vector maps, also see Chapter 27 for more information about **v.digit**)
- v.alabel[4] : Bulk-labels unlabeled area features in a binary GRASS vector file (allows you to set category numbers and optionally labels)
- v.llabel[5] : Bulk-labels unlabeled points or lines in a binary GRASS vector file (allows you to set category numbers and optionally labels)<

If you wish to create a new vector map on the basis of an old one, you can use one of two modules:

- v.reclass[6] : Creates a new map layer whose category values are based upon the user's reclassification of categories in an existing vector map layer
- v.extract[7] : Selects vector objects from an existing vector map and creates a new map containing only the selected objects

Notes

1. http://grass.itc.it/gdp/html_grass5/html/v.report.html
2. http://grass.itc.it/gdp/html_grass5/html/v.what.html
3. http://grass.itc.it/gdp/html_grass5/html/v.digit.html
4. http://grass.itc.it/gdp/html_grass5/html/v.alabel.html
5. http://grass.itc.it/gdp/html_grass5/html/v.llabel.html
6. http://grass.itc.it/gdp/html_grass5/html/v.reclass.html
7. http://grass.itc.it/gdp/html_grass5/html/v.extract.html

Chapter 31. Site Attributes

GRASS site (or point) data is stored in a text format which supports multiple dimensions, one integer category number and multiple floating point and text attributes.

To query the categories of an existing site file, use the following modules:

- s.what[1] : Allows the user to query site list descriptions
- d.what.sites[2] : Interactively query a single site list descriptions
- s.out.ascii[3] : Converts a GRASS site list file into an ASCII listing of site locations and their descriptions

The text format of the site file allows you to manipulate site categories and attributes directly. To create a site file with the attributes you desire, you can edit a file yourself and then copy it to the site_lists directory of your mapset: **cp NameOfYourSitesFile $GISDBASE/$LOCATION_NAME/$MAPSET/site_lists/**. If you want to change the attribute values of a site file, copy the file to your current working directory with **cp $GISDBASE/$LOCATION_NAME/$MAPSET/site_lists/NameOfYourSitesFile .** and change whatever values you would like to. When finished, just copy the file back with **cp NameOfYourSitesFile $GISDBASE/$LOCATION_NAME/$MAPSET/site_lists/**. See the man page for s.in.ascii[4] for details about the format.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/s.what.html
2. http://grass.itc.it/gdp/html_grass5/html/d.what.sites.html
3. http://grass.itc.it/gdp/html_grass5/html/s.out.ascii.html
4. http://grass.itc.it/gdp/html_grass5/html/s.in.ascii.html

Chapter 32. Data Management with PostgreSQL

See GRASS 5.0.x and PostgreSQL - First Steps[1] for a general introduction. Also see the man pages for the GRASS database commands[2].

Notes

1. http://freegis.org/cgi-bin/viewcvs.cgi/~checkout~/grass/src.garden/grass.postgresql/tutorial/inde
2. http://grass.itc.it/gdp/html_grass5/database.html

Chapter 33. Statistics and Reports

Often you will wish to see statistics summarizing the data that is contained in your maps. GRASS offers several modules that allow you to do this.

Modules for raster maps

1. Get summary information about a single raster map
   - r.cats[1] - Prints category values and labels associated with user-specified raster map layers.
   - r.describe[2] - Prints terse list of category values found in a raster map layer.
   - r.info[3] - Outputs basic information about a user-specified raster map layer
   - r.report[4] - Reports acres, hectares, or number of cells as well as miles, meters, or kilometer for each category in a raster map layer.
   - r.info[5] - Generates area statistics for raster map layers. Can print total area, number of cells, percent cover for each category. Can also print category value, row, and column, as well as easting and northing for each cell.
   - r.sum[6] - Sums up the raster cell values.
   - r.univar[7] - Univariate statistics for a GRASS raster map
   - r.surf.area[8] - Surface area estimation for rasters.

2. Get information about a single raster map at specific points
   - d.what.rast[9] - Allows the user to interactively query the category contents of multiple raster map layers at user-specified locations within the current geographic region.
   - r.what[10] - Queries raster map layers on their category values and category labels at specific easting and northing locations, which are typed in.
   - s.sample[11] - Sample a raster file at site locations.

3. Get information about a single raster map along transects or profiles
   - r.profile[12] - Outputs the raster map layer values lying on user-defined line(s)
   - r.transect[13] - Outputs raster map layer values lying along user defined transect line(s). Can output the raw values or the median or average.

4. Get information from two or more raster maps
   - Given a base map, get information for corresponding areas in a cover map
     - r.average[14] - Finds the average of values in a cover map within areas assigned the same category value in a user-specified base map.
     - r.median[15] - Finds the median of values in a cover map within areas assigned the same category value in a user-specified base map
     - r.mode[16] - Finds the mode of values in a cover map within areas assigned the same category value in a user-specified base map
     - r.statistics[17] - Category or object oriented statistics. Can calculate distribution, average, mode, median, standard deviation, variance, skewness, kurtosis, minimum, maximum, and sum for cells in a cover map given categories in a user-specified base map.

- r.volume[18] - Calculates the volume of data "clumps", and (optionally) produces a GRASS site_lists file containing the calculated centroids of these clumps.

- Quantify the relationship between two or more raster maps
  - r.coin[19] - Tabulates the mutual occurrence (coincidence) of categories for two raster map layers.
  - r.covar[20] - Outputs a covariance/correlation matrix for user-specified raster map layer(s).
  - r.distance[21] - Locates the closest points between objects in two raster maps.
  - m.ipf[22] - Iterative proportional fitting for error matrices. Uses an error or confusion matrix produced by r.coin or r.kappa, smooths zero counts, and does iterative proportional fitting to normalize the matrix.

Modules for vector maps

1. Get summary information about a single vector map
   - v.info[23] - Information about a vector map's boundaries, projection, data type, category number, data base location and mapset, and history are put into a table and written to standard output.
   - v.report[24] - Generates a table showing the area present in each of the categories of a user-selected data layer. Area is given in hectares, square meters, and square kilometers
   - v.stats[25] - Prints information about a binary GRASS vector map layer. Information includes the number of lines, nodes, areas, islands, and attributes.

2. Get information about a single vector map at specific points or in specific areas
   - v.area[26] - Display GRASS area and perimeter information for GRASS vector map. Then user can select area on map by clicking with mouse within the desired area. Selected area will be highlighted in selected color on graphics display. On regular screen area infomation will be displayed, in square meters, hectares, acres, and square miles, Perimeter measurements, in meters, feet, and miles, are also displayed.
   - v.distance[27] - Calculate the distance from a point to the nearest line or point in a vector map. User types in easting and northing coordinates.
   - v.what[28] - Query the category contents of a (binary) vector map layer at user-selected locations. The mouse can be used or easting and northing can be typed.

Modules for site maps

- s.info[29] - Reports attribute, label, and other information about a sites file
- s.univar[30] - Univariate statistics for a GRASS sites list
- s.normal[31] - Tests for normality for sites

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.cats.html
2. http://grass.itc.it/gdp/html_grass5/html/r.describe.html
3. http://grass.itc.it/gdp/html_grass5/html/r.info.html
4. http://grass.itc.it/gdp/html_grass5/html/r.report.html
5. http://grass.itc.it/gdp/html_grass5/html/r.info.html
6. http://grass.itc.it/gdp/html_grass5/html/r.sum.html
7. http://grass.itc.it/gdp/html_grass5/html/r.univar.html
8. http://grass.itc.it/gdp/html_grass5/html/r.surf.area.html
9. http://grass.itc.it/gdp/html_grass5/html/d.what.rast.html
10. http://grass.itc.it/gdp/html_grass5/html/r.what.html
11. http://grass.itc.it/gdp/html_grass5/html/s.sample.html
12. http://grass.itc.it/gdp/html_grass5/html/r.profile.html
13. http://grass.itc.it/gdp/html_grass5/html/r.transect.html
14. http://grass.itc.it/gdp/html_grass5/html/r.average.html
15. http://grass.itc.it/gdp/html_grass5/html/r.median.html
16. http://grass.itc.it/gdp/html_grass5/html/r.mode.html
17. http://grass.itc.it/gdp/html_grass5/html/r.statistics.html
18. http://grass.itc.it/gdp/html_grass5/html/r.volume.html
19. http://grass.itc.it/gdp/html_grass5/html/r.coin.html
20. http://grass.itc.it/gdp/html_grass5/html/r.covar.html
21. http://grass.itc.it/gdp/html_grass5/html/r.distance.html
22. http://grass.itc.it/gdp/html_grass5/html/m.ipf.html
23. http://grass.itc.it/gdp/html_grass5/html/v.info.html
24. http://grass.itc.it/gdp/html_grass5/html/v.report.html
25. http://grass.itc.it/gdp/html_grass5/html/v.stats.html
26. http://grass.itc.it/gdp/html_grass5/html/v.area.html
27. http://grass.itc.it/gdp/html_grass5/html/v.distance.html
28. http://grass.itc.it/gdp/html_grass5/html/v.what.html
29. http://grass.itc.it/gdp/html_grass5/html/s.info.html
30. http://grass.itc.it/gdp/html_grass5/html/s.univar.html
31. http://grass.itc.it/gdp/html_grass5/html/s.normal.html

Chapter 34. Overlay and Patch Maps

Look at:

- r.patch[1] - 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
- i.image.mosaic (script, not module; no man page) - script to mosaic (aerial) images. A new image will be created with extended colormap.
- r.mapcalc[2] - Raster map layer data calculator
- r.combine[3] - Allows category values from several raster map layers to be combined
- v.patch[4] - Creates a new binary vector map layer by combining other binary vector map layers
- v.cutter[5] - Polygon Cookie Cutter

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.patch.html
2. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html
3. http://grass.itc.it/gdp/html_grass5/html/r.combine.html
4. http://grass.itc.it/gdp/html_grass5/html/v.patch.html
5. http://grass.itc.it/gdp/html_grass5/html/v.cutter.html

Chapter 35. Create Buffers

Look at:

- r.buffer[1] - Creates a raster map layer showing buffer zones surrounding cells that contain non-NULL category values

GRASS5.0 does not have a buffer function for vector data.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.buffer.html

Chapter 36. Raster map algrebra with r.mapcalc

r.mapcalc[1] performs arithmetic on raster map layers. New raster map layers can be created which are arithmetic expressions involving existing raster map layers, integer or floating point constants, and functions.

Please read the tutorials[2] (a bit outdated, but still valid for most of the basic operations.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html
2. http://grass.itc.it/gdp/html_grass5/Postscript/

Chapter 37. Coordinate Systems

Introduction to projections and coordinate systems

From the r.proj[1] man page:

"Map projections are a method of representing information from a curved surface (usually a spheroid) in two dimensions, typically to allow indexing through cartesian coordinates. There are a wide variety of projections, with common ones divided into a number of classes, including cylindrical and pseudo-cylindrical, conic and pseudo-conic, and azimuthal methods, each of which may be conformal, equal-area, or neither.

The particular projection chosen depends on the purpose of the project, and the size, shape and location of the area of interest. For example, normal cylindrical projections are good for maps which are of greater extent east-west than north-south and in equatorial regions, while conic projections are better in mid-latitudes; transverse cylindrical projections are used for maps which are of greater extent north-south than east-west; azimuthal projections are used for polar regions. Oblique versions of any of these may also be used. Conformal projections preserve angular relationships, and better preserve arc-length, while equal-area projections are more appropriate for statistical studies and work in which the amount of material is important.

Projections are defined by precise mathematical relations, so the method of projecting coordinates from a geographic reference frame (latitude-longitude) into a projected cartesian reference frame (eg metres) is governed by these equations. Inverse projections can also be achieved. The public-domain Unix software package PROJ.4[2] has been designed to perform these transformations, and the user's manual contains a detailed description of over 100 useful projections. This also includes a programmers library of the projection methods to support other software development.

Thus, converting a "vector" map - in which objects are located with arbitrary spatial precision - from one projection into another is usually accomplished by a simple two-step process: first the location of all the points in the map are converted from the source through an inverse projection into latitude-longitude, and then through a forward projection into the target. (Of course the procedure will be one-step if either the source or target is in geographic coordinates.)

Converting a "raster map", or image, between different projections, however, involves additional considerations. A raster may be considered to represent a sampling of a process at a regular, ordered set of locations. The set of locations that lie at the intersections of a cartesian grid in one projection will not, in general, coincide with the sample points in another projection. Thus, the conversion of raster maps involves an interpolation step in which the values of points at intermediate locations relative to the source grid are estimated."

Projections in GRASS

See the list of supported projections[3] for an idea of which projections are supported in GRASS.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.proj.html
2. http://www.remotesensing.org/proj/
3. http://grass.itc.it/gdp/html_grass5/projections.html

Chapter 38. Project data

In GRASS, if you want to change the projection of a map, or, more precisely, create a copy of the map in another projection, you have to create a new location (see Chapter 16) with the new projection and coordinate system you wish to use. Then, according to the type of map, you can use the following commands to project the map from its original location to the new one:

- r.proj[1] for raster maps
- v.proj[2] for vector maps
- s.proj[3] for site maps

If for any reason a location does not contain projection information (stored in the PROJ_INFO and PROJ_UNITS files), you can create it with the g.setproj[4] command.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.proj.html
2. http://grass.itc.it/gdp/html_grass5/html/v.proj.html
3. http://grass.itc.it/gdp/html_grass5/html/s.proj.html
4. http://grass.itc.it/gdp/html_grass5/html/g.setproj.html

Chapter 39. Raster to Vector

There are three modules you can use to convert a raster to a vector map, depending on the type of objects you wish to convert.

Lines

If you want to convert raster lines to vector lines, you first have to make sure that the raster lines are thin enough to be transformed into only one vector line respectively, and not into several parallel lines. "Thin enough" actually means having a width of only one cell. The module to use for this operation is r.thin[1].

Once you have thinned the raster lines, you can use r.line[2] to transform the raster data into vector data. Don't forget to run v.support[3] after **r.line**. The quality of the resulting vector lines depends on the resolution of the original raster data.

Areas

For transformation of raster areas into vector area lines you can use r.poly[4]. If you use the "-l" option, the module will smooth the corners to avoid the blocky appearance of raster areas. Be aware that, depending on the resolution of the raster map and of the original data, this smoothing might induce a certain error. Again, don't forget to run v.support[5] after the transformation. The cell category values for the raster map layer will be used to create attribute information for the resultant vector areas.

Contours

You can transform a raster surface into vector isolines (or contours) with the r.contour[6] module. If you just give it the interval between lines ("step" command line option), it automatically determines the other values. You can also define a fixed series of levels at which you would like to see isolines ("levels" option). The module automatically runs **v.support** for you, so you don't have to worry about that.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.thin.html
2. http://grass.itc.it/gdp/html_grass5/html/r.line.html
3. http://grass.itc.it/gdp/html_grass5/html/v.support.html
4. http://grass.itc.it/gdp/html_grass5/html/r.poly.html
5. http://grass.itc.it/gdp/html_grass5/html/v.support.html
6. http://grass.itc.it/gdp/html_grass5/html/r.contour.html

Chapter 40. Raster to Sites

You can create a site file from a raster file using r.to.sites[1]. This will create a site for every non-NULL cell of your raster map. You might want to adapt your region settings to a lower resolution in order to have less sites in the result (see Chapter 12.

Another command that might be useful in this context is s.sample[2] which samples a raster map at the site locations in the input (site) file by either cubic convolution interpolation, bilinear interpolation, or nearest neighbor sampling.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.to.sites.html
2. http://grass.itc.it/gdp/html_grass5/html/s.sample.html

Chapter 41. Vector to raster

You can use v.to.rast[1] to transform all labeled (!) vectors into a raster map. Unlabeled vectors will be omitted.

Beware that the command uses the current region settings, so make sure they encompass the region you would like to transform into a raster map. Also, when creating fixed category area maps ("thematic maps") that don't need a high resolution, make sure that the resolution is not set too high, as that might make the transformation uneccessarily slow (see Chapter 12).

If you wish to interpolate raster data from vector data, several options exist:

- v.surf.rst[2] - interpolation and topographic analysis from given contour data in vector format to floating point raster format using regularized spline with tension
- r.surf.contour[3] - creates a raster elevation map from a rasterized contour map (in combination with **v.to.rast**)

Notes

1. http://grass.itc.it/gdp/html_grass5/html/v.to.rast.html
2. http://grass.itc.it/gdp/html_grass5/html/v.surf.rst.html
3. http://grass.itc.it/gdp/html_grass5/html/r.surf.contour.html

Chapter 42. Vector to Sites

The command v.to.sites[1] allows you to either transform vector points into sites data, or (using the -a flag) to create a sites file containing all the vertices of the vector file as sites.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/v.to.sites.html

Chapter 43. Sites to raster

To transform a sites file into a raster file, use s.to.rast[1] which by default fills one cell per site. Depending on the region settings this might be very small, so play around with the 'size=' option to make them larger.

You also have different options for interpolation from site data to raster data:

- s.surf.rst[2] - interpolation and topographic analysis from given site data to GRASS floating point raster format using regularized spline with tension
- s.surf.idw[3] - surface interpolation from sites data by Inverse Distance Squared Weighting
- s.vol.rst[4] - interpolates point data to a G3D grid volume using regularized spline with tension (RST) algorithm

Notes

1. http://grass.itc.it/gdp/html_grass5/html/s.to.rast.html
2. http://grass.itc.it/gdp/html_grass5/html/s.surf.rst.html
3. http://grass.itc.it/gdp/html_grass5/html/s.surf.idw.html
4. http://grass.itc.it/gdp/html_grass5/html/s.vol.rst.html

Chapter 44. Sites to vector

Several modules allow you to create vector files from site files:

- s.to.vect[1] - converts a site_lists file into a vector file
- s.voronoi[2] - uses a sites list to produce a Voronoi diagram as a vector file
- s.delaunay[3] - creates a vector delaunay triangulation from a sites file
- s.hull[4] - uses a sites list to produce a convex hull vector map

Notes

1. http://grass.itc.it/gdp/html_grass5/html/s.to.vect.html
2. http://grass.itc.it/gdp/html_grass5/html/s.voronoi.html
3. http://grass.itc.it/gdp/html_grass5/html/s.delaunay.html
4. http://grass.itc.it/gdp/html_grass5/html/s.hull.html

Chapter 45. Preprocessing Images

Import and export of imagery data

Imagery data is raster data, so you can import it with the infamous r.in.gdal[1] module. Especially its capacity to create a new location on the fly is very helpful in this context. Other more specialized import modules exist, such as i.in.erdas[2], r.in.bin[3], etc. In general, try r.in.gdal first and if that doesn't work, try the rest. Since image data is recorded at different wave lengths, it is often split into different images representing different ranges of wave lengths (such as red, green, blue, infrared, thermal, etc).

There is just one specialized image export model, i.out.erdas[4] which, as you might have guessed, allows you to create ERDAS files and can export several channels. You obviously can also use any of the (raster export modules[5]) for exporting single channel images.

Image groups

Since most image data comes in multiple channels representing different rqnges of zave lengths, GRASS needs to know which raster data files correspond to one image. This is what groups are for, and groups are created with i.group[6]. As the man page for this module says: "i.group allows the user to collect raster map layers in an imagery group by assigning them to user-named subgroups or other groups. This enables the user to run analyses on any combination of the raster map layers in a group." Please see the man page for further information about its use.

Geocoding of images

Depending on how much money you can spend, the data you dispose of will be geocoded or no. For any sensible use geocoding is indispensable, so if you can't pay it, you'll have to do it yourself.

If you're part of the upper classes of image processors and in proud possession of geocoded data, just relax at the pool while the rest of us goes to work, unless you wish to work in a different projection than the one your data comes in. If you need help for that, please follow the links listed in Chapter 38. For the rest of us, let's go on.

In order to geocode an image, we need reference points for which we know the precise coordinates in the projection system we want to use. Those points are called ground control points or GCP. If you're of those that win in lotteries your data actually might contain GCP. In that case, **r.in.gdal** will store those points in a POINTS file and can even reproject them during import if you use the "target=" parameter. However, the lower masses and those whose GCP are not sufficient to reach an acceptable accuracy will have to identify the points themselves. Luckily GRASS offers you some help with this task.

Before doing anything else, you will have to group your data with i.group[7]. Once this is done, please identify the target location (which you have created before using the instruction in Chapter 16) with i.target[8]. This defines the projection system into which you will recitfy your data.

The main tools for rectifying your images are i.points[9] and i.rectify[1011]. The first allows you to juxtapose one of the images of your group[14] with a raster reference map (use the option "PLOT RASTER" to use such a reference map). A zoom function helps you identify the points at sufficient precision level. At any moment you can calculate the root mean square error for the points entered and thus control the precision. Please see the man page for a complete description of how to use the module. Note that you need an open graphics monitor to use it. If you would rather use a vector map as reference map, you can use the module i.vpoints[15].

i.rectify[16] will use the points you defined with i.points[17] to ... rectify your image. In other words it geocodes your map by linking the data elements contained in your image to geographical coordinates. The module is pretty straightforward, but if questions remain, consult the man page.

Colors

Use r.colors[18] to redefine the color table of your images. For example, you can use the "color=grey.eq" parameter setting to apply a contrast stretch to an image (useful for those that appear too dark).

Displaying images

In order to display your image in a recognizable way you have to create a color composite from its different frequency channels. Thus, to get a natural color composite you would combine the red, green and blue channels. Two options are open to you:

- Simply display a composite with d.rgb[19]. This does not create a new map, but displays three layers in a composite form.
- Create a new composite map. For this purpose you can use i.composite[20]. This is also very useful if you need a color composite as base map, as for example for geocoding or for classification.

Radiometric preprocessing

In order to avoid certain phenomena such as atmospheric and terrain effects, but also image transformation by the vendor, several corrections need to be applied to your image data before you can procede to serious analysis. For most of these corrections you should use r.mapcalc[21] (see Chapter 36 for links to general tutorials on this module and see the relevant litterature for more information on radiometric techniques).

Notes

1. http://grass.itc.it/gdp/html_grass5/html/r.in.gdal.html
2. http://grass.itc.it/gdp/html_grass5/html/i.in.erdas.html
3. http://grass.itc.it/gdp/html_grass5/html/r.in.bin.html
4. http://grass.itc.it/gdp/html_grass5/html/i.out.erdas.html
5. http://grass.itc.it/gdp/html_grass5/raster.html
6. http://grass.itc.it/gdp/html_grass5/html/i.group.html
7. http://grass.itc.it/gdp/html_grass5/html/i.group.html
8. http://grass.itc.it/gdp/html_grass5/html/i.target.html
9. http://grass.itc.it/gdp/html_grass5/html/i.points.html
10. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
11. You can also try

    12. http://grass.itc.it/gdp/html_grass5/html/i.points3.html
    and

    13. http://grass.itc.it/gdp/html_grass5/html/i.rectify3.html
    which are more recent, but still unfinished modules.

12. http://grass.itc.it/gdp/html_grass5/html/i.points3.html

13. http://grass.itc.it/gdp/html_grass5/html/i.rectify3.html
14. You might want to create a color composite image and include it into your group in order to display it.
15. http://grass.itc.it/gdp/html_grass5/html/i.vpoints.html
16. http://grass.itc.it/gdp/html_grass5/html/i.rectify.html
17. http://grass.itc.it/gdp/html_grass5/html/i.points.html
18. http://grass.itc.it/gdp/html_grass5/html/r.colors.html
19. http://grass.itc.it/gdp/html_grass5/html/d.rgb.html
20. http://grass.itc.it/gdp/html_grass5/html/i.composite.html
21. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html

Chapter 46. Analyzing Images

Introduction

Image analysis is a wide field with lots of different techniques that would be far to many to describe here. We will, therefore, only briefly mention some of the more common ones. Don't hesitate to browse through the man pages of the imagery modules[1] and of the raster modules[2] for inspiration and consult the tons of litterature that exist on the topic of image anlysis (TODO: add references).

Image ratios

One quite simple way of analyzing images is by using image ratios in which you use the input of two or more frequency bands of your image in order to calculate an index (such as the often-used normalized difference vegetation index) or to enhance your image. See the relevant litterature for their uses. In GRASS you can calculate such ratios with r.mapcalc[3].

Factor analysis

One way of synthesizing the information contained in the different bands (which often contain overlapping, i.e. redundant, information) is the use of principal component analysis in order to perform a principal component tranformation. Thus the information contained in the different channels of your image will be reduced to fewer, mutually independent newly-created variables that can be displayed as images. GRASS offers the i.pca[4] module for this task. Another option is a canonical component analysis with i.cca[5].

Fourier transformation

In order to analyze the frequency distributions of your images, for example in order to identify periodic noise, you can use Fourier transformation. In GRASS, use the i.fft[6] module that implements the Fast Fourier Transform algorithm and "constructs the real and imaginary Fourier components in frequency space". To recreate a normal image out of the real and imaginary components, use i.ifft[7].

Image filtering

You can use filtering to enhance you image, for example through contrast improvement or smoothing, or to detect edges. You can obviously use r.mapcalc[8] to construct any filter you like, but GRASS also offers the module r.mfilter[9] which allows quite easy construction of sequential or parallel filters, possibly several at once. If you want to apply frequency filters, you can use the fft modules discussed above in combination with r.circle[10]

Notes

1. http://grass.itc.it/gdp/html_grass5/imagery.html
2. http://grass.itc.it/gdp/html_grass5/raster.html
3. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html
4. http://grass.itc.it/gdp/html_grass5/html/i.pca.html
5. http://grass.itc.it/gdp/html_grass5/html/i.cca.html
6. http://grass.itc.it/gdp/html_grass5/html/i.fft.html

7. http://grass.itc.it/gdp/html_grass5/html/i.ifft.html
8. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html
9. http://grass.itc.it/gdp/html_grass5/html/r.mfilter.html
10. http://grass.itc.it/gdp/html_grass5/html/r.circle.html

Chapter 47. Classifying Images

Introduction

One very common task concerning images is classification. In order to use the images for mapping or further analysis, it is often interesting to translate the frequency information contained in images into thematic information such as land use or state of vegetation. You generally have the choice between two approaches: supervised or unsupervised image classification.

Unsupervised classification

Unsupervised classification consists of letting the computer automatically calculate classes on the basis of several (more than one) frequency bands of you image. This leaves you with the task of identifying the right number and the real world meaning of the resulting classes. For unsupervised classification go through the following steps:

creation of group and subgroup

If not already done, you have to create a group and a subgroup containing the files you wish to classify. Use i.group[1] to do so.

clustering

Use i.cluster[2] to create the classes from your images. The man page explains all the parameters. You can optionally give a seed signature file to **i.cluster** which contains definitions of classes resulting from a previous clustering session or from a supervised clustering procedure. This seed file should help you optimize the cluster decision boundaries.

classification

Now that you have created your class definitions, you have to reclassify your original image to decide to which class each individual pixel belongs. As always (well, almost always), GRASS has a solution for you: i.maxlik[3], a "maximum-likelihood discriminant analysis classifier". This takes the signature file ("sigfile") generated by **i.cluster** to assign each pixel to a class based on probabilities of likelihood. The resulting map will show you the classes in your original map. The optional "reject" parameter allows you to create a raster map containing the confidence levels for each pixel.

Supervised classification

In supervised classification you do not let the computer create the classes, but you create them yourself and let the computer only do the second step, i.e. the assignment of pixels to the classes. This means that you determine beforehand the number and the nature of the classes you wish to use. Follow these steps for supervised classification:

creating the classes

GRASS allows you to create the classes by determining so-called "training areas" in existing maps. Such training-areas have to represent a homogenous sample for them to work. The module i.class[4] helps you in defining those areas. It lets you display a map (such as, for example, a color composite created with i.composite[5])

and identify homogenous areas in this map. The spectral signatures of these areas will then be saved and can then be used as classes in i.maxlik[6].

classification

This is the same as for the unsupervised classification: use i.maxlik[7] for this step.

Partially supervised classification

An intermediate path between the two above option is the use of i.gensig[8]. This module crates the spectral signatures automatically for you, based on a training map you provide. This training map should contain already classified training areas. You can create a training map using v.digit[9] or r.digit[10] or by extracting relevant features with v.extract[11] or r.mapcalc[12].

Notes

1. http://grass.itc.it/gdp/html_grass5/html/i.group.html
2. http://grass.itc.it/gdp/html_grass5/html/i.cluster.html
3. http://grass.itc.it/gdp/html_grass5/html/i.maxlik.html
4. http://grass.itc.it/gdp/html_grass5/html/i.class.html
5. http://grass.itc.it/gdp/html_grass5/html/i.composite.html
6. http://grass.itc.it/gdp/html_grass5/html/i.maxlik.html
7. http://grass.itc.it/gdp/html_grass5/html/i.maxlik.html
8. http://grass.itc.it/gdp/html_grass5/html/i.gensig.html
9. http://grass.itc.it/gdp/html_grass5/html/v.digit.html
10. http://grass.itc.it/gdp/html_grass5/html/r.digit.html
11. http://grass.itc.it/gdp/html_grass5/html/v.extract.html
12. http://grass.itc.it/gdp/html_grass5/html/r.mapcalc.html

Chapter 48. Introduction

GRASS offers several different solutions for cartography, none of which are very user-friendly in the sense of point-and-click interfaces, but once you get used to them, they can be very efficient. You can either export a map as a raster file with the CELL and the PNG drivers, create a postscript file with the ps.map module or create an htmlmap file with the HTMLMAP driver.

Since GRASS does not offer any interactive layout tools, it often advisable to import the output of GRASS into a drawing program allowing a finer control of placements.

Chapter 49. Map export to raster image files

To allow you to export what you would normally see on your screen to a raster file, there are two alternative "monitor" drivers to the standard terminal monitors. These are the CELL[1] driver and the PNG[2] driver. Both are started just like a normal monitor and from that point on, all display commands are directed into the resulting raster file and not to a terminal monitor.

The difference between the two is that the CELL driver creates a GRASS raster file that you then have to export using one of the r.out.* raster export[3] modules, whereas the PNG driver directly creates a file outside of GRASS.

PNG driver

The PNG driver has the advantage of exporting directly to an external file. Its disadvantage is the fact that it depends on the libpng library which might not always be present on all systems (although it should be on many). Its usage is very simple:

d.mon start=PNG

any display[4] commands

d.mon stop=PNG

This creates a file map.png in the current directory containing all the layers that you drew with the display commands. You can use environmental variables to set options such as an alternative file name, the resolution of the resulting image, the background color, etc. Please the manual page[5] for more details.

CELL driver

The CELL driver is a bit more complicated to use, as it requires the extra step of exporting the resulting CELL file to an external raster file. It has the advantage, however, of using internal GRASS routines, and, therefore, not being dependent on external libraries. Other than that its usage is exactly the same as the PNG driver. See the manual page[6] for details and differences.

Very important: before exporting the D_cell raster file which is the output of the CELL driver, you will have to set the region to cover this file (otherwise your export results will be empty):

g.region rast=D_cell

Scripting the creation of maps

By definition you will not see the results of your display commands when you direct them into one of the above drivers. You, therefore, might want to test your commands in a normal monitor before (or test in the Display Manager, see the Section called *Creating a PNG map from the Display Manager* below. You can then enter all the commands into a text file which you can then launch once you have started the driver of your choice. Or you can use d.save[7] to help you create the script file.

d.mon start=PNG

sh your_text_file

d.mon stop=PNG

Often, one needs to create several maps with a similar layout. In that case it would be quite tedious to retype the same commands over and over again. Again, the use of a script file can be very helpful here. Just change the names and options of the maps to be displayed, relaunch the driver and rerun the script. (But be careful: if you do not

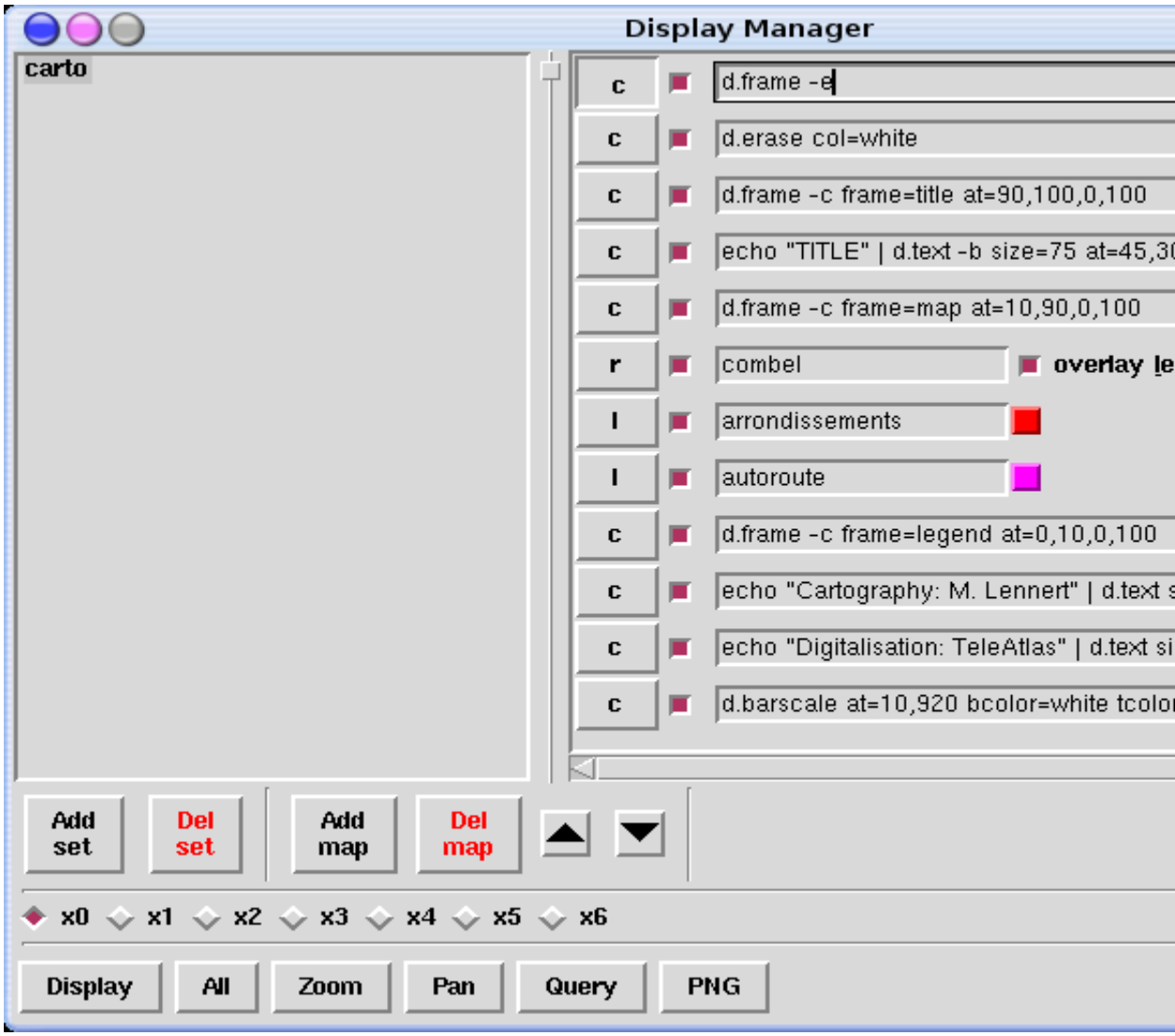
rename the result at each run of the driver, or change the GRASS_PNGFILE variable in the case of the PNG driver, your new map will overwrite the previous one !)

If you combine the scripting with the use of d.frame[8], you can create quite sophisticated layouts. Here's a (very) simple example of such a layout script:

```
d.frame -e # erase any existing frames
d.erase col=white # create a white background
d.frame -c frame=title at=90,100,0,100 # create a title frame
echo "TITRE" | d.text -b size=75 at=45,30 col=black # write the title
d.frame -c frame=map at=10,90,0,100 # create a map frame
d.rast combel # draw a raster map
d.vect arrondissements col=red # draw a vector map
d.vect autoroute col=violet # draw a second vector map
d.frame -c frame=legend at=0,10,0,100 # create a legend frame
echo "Cartography: M. Lennert" | d.text size=20 at=75,50 col=black # draw text
echo "Digitalisation: TeleAtlas" | d.text size=20 at=75,30 col=black # draw more text b
d.barscale at=10,920 bcolor=white tcolor=black # create a barscale
```

Creating a PNG map from the Display Manager

If you are involved in one of those "anti-command line leagues", GRASS offers you a compromise in the form of the Display Manager[9]. The interface includes a "PNG" button which allows you to put into a `map.png` file everything that you see on the screen when pushing the "Display" button (except for legends). In addition, you have the choice of entering a "command" instead of a specific map type. This allows you to enter any command that you might use in GRASS, as for example **d.frame**. The script example above, would look like this in **d.dm**:



From there, just click on the "PNG" button and you have your map (don't forget to rename it, or it will be overwritten by the next run of the PNG driver). Use the "Add set" button and the "Save" button to create different types of layouts that you can then reuse with different maps (TIP: double-click on a set to rename it...).

Notes

1. http://grass.itc.it/gdp/html_grass5/html/celldriver.html
2. http://grass.itc.it/gdp/html_grass5/html/pngdriver.html
3. http://grass.itc.it/gdp/html_grass5/raster.html
4. http://www.geog.uni-hannover.de/grass//gdp/html_grass5/display.html
5. http://grass.itc.it/gdp/html_grass5/html/pngdriver.html
6. http://grass.itc.it/gdp/html_grass5/html/celldriver.html
7. http://grass.itc.it/gdp/html_grass5/html/d.save.html
8. http://grass.itc.it/gdp/html_grass5/html/d.frame.html
9. http://grass.itc.it/gdp/html_grass5/html/d.dm.html

Chapter 50. Postscript Maps/Exports

The ps.map[1] module offers the possibility to create very fine-tuned maps in postscript. Next to some interesting options that do not exist as display commands in GRASS, the great advantage over the raster export drivers is the fact that the postscript format can be transformed into a vector format which allows reworking parts of the file in vector graphics programs (see the Section called *Editing the resulting postscript file with pstoedit* for more details).

For beginners, the possibility of interactive usage of ps.map is very helpful, but many of its options are not available interactively and it is, therefore, recommended to create a script file with the instructions, once you are familiar with the general concept.

Interactive usage

For newcomers to ps.map, this is the best way to begin to learn the usage of ps.map. Just answer the questions, and be sure, at the end, to answer "y" to the question "do you want to save the script file? (y/n)". This will allow you to look at a script file in order to learn from it and adapt it for more fine-grained control (see next subsection). In order to visualize your map, use the postscript viewer of your system (ghostview, gv, etc...).

Scripted usage

This is where the entire power of ps.map really comes to play. Just have a look at all the commands listed on the manual page[2] and you will get an idea of the possibilities offered. Having to write commands into a script file might seem a bit scary to some and definitely seems a bit outdated in our times of "point the mouse and let the computer do the rest for you", but once you understand the basic principles of ps.map, and once you have one or two finished script files at hand (created, for example, through interactive usage of **ps.map**), you will soon feel the convenience of just typing a few commands to create a very decent layout for your maps. This is also very practical when you work in a team as you can create one template script which will create the same layout for everyone and in which each team member only has to add a few commands to draw her maps.

All the commands are listed and explained on the manual page[3], so we won't cover those here. Be sure to look at the example script at the end of that page. However, here are some tips that might help you:

- One frequent source of error is the omission of an **end** statement at the end of a command block. Always include these, as they also help you make your script more readable.
- In the same line, use comments in your file to explain what you are doing (comments are anything written after a "#" character) and use line spaces to make it readable.
- In general, you can trust ps.map to place items correctly, so only use the "where=" if you are not satisfied with the automatic placements.
- If you use the **colortable** command on a raster file with many different values, try the "cols" option in order to get all your classes onto the map.
- As one of the hidden treasures of GRASS, there is a **ps.map.barscale** module that creates a GRASS vector file and a ps.map script file for a barscale. Just launch the command, answer the questions and include the resulting script file into your general ps.map script file (possibly with the **read** command).

Generally, all you have to do once you have a script ready, is launch ps.map as follows:

ps.map in=NameOfYourScriptFile out=NameOfThePSFile

Easy, isn't it ? ;-)

Editing the resulting postscript file with pstoedit

The file containing your finished map after running **ps.map** is in postscript, the universal printing command language. There are not many programs that allow you to edit a postscript file directly (well, actually there are: text editors, but unless you are willing to learn the entire postscript command language, this won't be of much help to you). So, you can normally use your postscript file only in the same way you would a raster graphics file (i.e. .png or .jpeg), meaning that you cannot edit individual objects of the map, only each individual pixel.

However, there is a very handy little free software tool called pstoedit[4], written by Wolfgang Glunz. This allows you to transform your postscript file into a host of different vector formats which you can then edit easily in the relevant vector graphics program. For example, in order to translate a postscript file into a skencil[5] (formerly "sketch") file, just type:

pstoedit -f sk YourPostscriptFile.ps ResultingFileName.sk

Then you can edit the entire map, including individual areas, lines and points in the skencil program.

Notes

1. http://grass.itc.it/gdp/html_grass5/html/ps.map.html
2. http://grass.itc.it/gdp/html_grass5/html/ps.map.html
3. http://grass.itc.it/gdp/html_grass5/html/ps.map.html
4. http://www.pstoedit.net/pstoedit/
5. http://sketch.sourceforge.net/

Chapter 51. HTML Maps/Exports

Chapter 52. Using external programs for map layout

Since GRASS is specialized in geographical information management and not in graphical layout, it is often necessary to rework the resulting maps in a real graphics program. Several such programs exist in the free software world, and you will just have to choose the one you prefer personally. We can divide them into those that use formats that you can transform your postscript file into (using pstoedit[1] - see the Section called *Editing the resulting postscript file with pstoedit* in Chapter 50), therefore allowing direct editing, and those that can only import non-editable raster files (e.g. PNG):

Editable vector import

- Skencil[2]
- XFig[3]
- Other suggestions ?

Non-editable raster import

- OpenOffice Draw[4]
- Tgif[5]
- Other suggestions ?

Notes

1. http://www.pstoedit.net/pstoedit
2. http://sketch.sourceforge.net/
3. http://www.xfig.org/
4. http://www.openoffice.org/product/draw.html
5. http://bourbon.usc.edu:8001/tgif/index.html

Chapter 53. Scripting GRASS

Scripts

The possibility to automate individual steps is a very useful extension (even for GRASS beginners). These scripts have to be written in ASCII format as UNIX shell scripts. Within those scripts GRASS modules can be called with their respective parameters and geostatistical computations can be done automatically. Especially for novices it is a good idea to generate scripts step by step, trying the commands on command line in the terminal first. Later the UNIX command \texttt{\$~history} allows viewing and saving ("copy" - "paste" into a text editor with left and middle mouse button) the previously entered commands.

Here[1] is an example that shall demonstrate the potential of script programming clearly: with this script you can calculate general geostatistical information for raster images[2]. Save this script as, for example, `statistics.sh` and set the UNIX permissions with **chmod u+x statistics.sh**.

This script can be used after launching GRASS, specify the name of the raster map to be analyzed as parameter. A modified version of above script exists in GRASS 5 under the name of **r.univar**. In here the output of the GRASS module r.stats[4] is transferred to the UNIX program **awk** by UNIX piping (represented by the '|' character). The calculations are done within awk, results are printed on the screen.

The best way to understand GRASS scripting is definitely by studying the many existing examples. Just go to the scripts directory if your GRASS implementation and study some of them:

cd $GISBASE/scripts/

A few GRASS modules will help you in your scripts. Those are:

- g.ask[5] for comfortable querying the user for map names from the GRASS database
- g.findfile[6] to directly find a file in the GRASS database and process it
- g.gisenv[7] to query for the settings of some of the GRASS environment variable such as GISDBASE, LOCATION and MAPSET.

Study their use in the existing GRASS scripts to understand how they work.

For more information on general shell programming please consult the man page of your shell (on GNU/Linux this is generally the bash shell, so type **man bash** or follow on of the many links listed on the Programming Texts and Tutorials[8] page.

Batch usage of GRASS

GRASS can be completely controlled externally through scripts (and therefore run automatically) by setting the correct environment variables. There doesn't exist a single "GRASS" program, in fact GRASS is a collection of modules which are run in a special environment. Even the GRASS startup is simply setting numerous variables. This can be done directly as well, here[9] an example in "bash-shell" style.

After having run this script, all GRASS modules that can be used non-interactively can be used. Generally, you can get the list of parameters required by a module by typing "-help" as such a parameter or (always recommended) by reading the manual.

Once these variables have been set, GRASS can also be integrated into CGI, PERL and other scripts. You can visit a quite complex example on the internet: SlideLinks[10] which is an online GIS based completely on CGI scripts, a database management system and GRASS.

Since GRASS 5.0 you can alternatively skip the startup screen by directly specifying the database, location and mapset:

grass5 /home/neteler/grassdata/katmandu/innercity

Obviously, this only works if the location and the other settings really exist.

Notes

1. http://mpa.itc.it/grasstutor/scripts/statistics.sh.txt
2. The code example links in this chapter go to
   3. http://mpa.itc.it/grassbook/
   .
3. http://mpa.itc.it/grassbook/
4. http://grass.itc.it/gdp/html_grass5/html/r.stats.html
5. http://grass.itc.it/gdp/html_grass5/html/g.ask.html
6. http://grass.itc.it/gdp/html_grass5/html/g.findfile.html
7. http://grass.itc.it/gdp/html_grass5/html/g.gisenv.html
8. http://stommel.tamu.edu/~baum/programming.html#shells
9. http://mpa.itc.it/grasstutor/scripts/grass_batch.sh.txt
10. http://gisws.media.osaka-cu.ac.jp/grasslinks/

Chapter 54. C-Programming

All important aspects of C programming for GRASS are described in the GRASS 5.0 Programmer's Manual (PDF, 2.3MB)[1]. This section shall just give an overview how GRASS modules are usually structured. Generally, it will be helpful to look at some of the (over 350) existing modules as examples for learning (you can browse the source code via the CVS web interface[2]). Only an "open source" GIS such as GRASS offers these deep insights into the "heart" of a GIS. The general structure of the modules is always similar, each module is stored in a directory of the GRASS source code.

The current source code structure is as follows:[3]

GRASS GIS library (most relevant only):

html/
: modules descriptions

src/CMD/
: internal scripts for compilation

src/include/
: header files

src/libes/
: GIS library routines

src/display/devices/
: display driver

src/fonts/
: character fonts

src/front.end/
: internal routines for the interactive mode of modules

Modules (standard tree):

src/display/
: modules for displaying maps on the GRASS monitor

src/general/
: file management modules

src/imagery/
: image processing modules

src/mapdev/
: vector modules

src/misc/
: miscellaneous modules

src/paint/
: paint driver (PPM)

src/ps.map/
: postscript driver

src/raster/
: raster modules

src/scripts/
: scripts

src/sites/
: point modules

src/tcltkgrass/
: Tcl/Tk GUI

Other modules:

src.contrib/
: contributions of various institutions (however, many are in standard tree as well)

src.garden/
: modules with linked simulation models and various interfaces

The existing GRASS modules are built upon the "GRASS programming library" which offers a multitude of GIS functions. It is structured as follows (square brackets contain the typical function name prefixes for the respective library routines):

GIS library:
: database routines (GRASS file management), memory management, parser (string analysis), projections, etc. [G_]

vector library:
: management of area, line, and site vectors [Vect_, V2_, dig_]

raster library:
: raster data management [R_]

site data library:
: site data management [G_sites_]

display library:
: graphical output to the monitor [D_]

driver library:
: printer driver

image data library:
: image processing file management [I_]

segment library:
: segmented data management [segment_]

vask library:

control of cursor keys etc. [V_]

rowio library:

for parallel row analysis of raster data [rowio_]

Some of the routines offered are quite substantial. For example they allow calculating geodesic distances out of given coordinate points, others perform queries on vector areas (e.g.: point-in-polygon tests).

Modules consist of the C program files (*.c), the header files (*.h) and a `Gmakefile`. GRASS has its own "make" routine: **gmake5**. The file `Gmakefile` contains instructions concerning the files to be compiled and the libraries to be used (GRASS and UNIX libraries). It has a specific pattern that must be respected. A simple example[5] (important: indents with tab, not with space!) shall demonstrate the typical structure.[6]

The line "\$(HOME)/\$(PGM)..." and the next contain the compiler instructions, above this section the variables are set. Variables not set here are defined automatically in

`grass5/src/CMD/head/head.$ARCH`

where $ARCH is the name of the system architecture. Starting from GRASS 5.0 this "head" file is created automatically for the used computer platform by the "configure" script, which has to be run before the first compilation. The $(HOME) variable indicates where the binary file (i.e. the module) will be copied to: in this example it is the standard path for modules that offer command line support (no limitation to interactive only usage): `grass5/etc/bin/cmd/`.

The actual C program should be divided by (sub-)functionality into several files which have to be listed respectively in the list of objects in the `Gmakefile`. For details please refer to the "GRASS Programmer's manual" as this book cannot cover a full C programming tutorial. GRASS GIS library commands can be used directly in the source code. Interactive parameter querying is made possible by GRASS-specific parameter programming. Here[8] is a short example of a raster module.

The calculation is done row and column wise (see "for" loop). As denoted above, it is advisable to divide the entire module into individual, thematically organized files in order to facilitate program maintenance.

Notes

1. http://grass.itc.it/grass5/progmangrass50.pdf
2. http://freegis.org/cgi-bin/viewcvs.cgi/
3. This will change with new versions of GRASS in an effort to put more common routines into libraries and with the integration of a completely new vector engine (see the
   4. http://grass.itc.it/grass51/manuals/
).
4. http://grass.itc.it/grass51/manuals/
5. http://mpa.itc.it/grasstutor/scripts/code_Gmakefile_pre4
6. The code example links in this chapter go to
   7. http://mpa.itc.it/grassbook/
   .
7. http://mpa.itc.it/grassbook/
8. http://mpa.itc.it/grasstutor/scripts/landsat.c

Chapter 55. Digital Terrain Models

GRASS - Geographic Resources Analysis Support System

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Chapter 56. Topographical analysis

GRASS - Geographic Resources Analysis Support System

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Chapter 57. Cost Surfaces

GRASS - Geographic Resources Analysis Support System

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Chapter 58. Creating Animations

GRASS - Geographic Resources Analysis Support System

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Chapter 59. Bibliography

GRASS - Geographic Resources Analysis Support System[1]

See GRASS Documentation project[2] (Books and tutorials). Major parts of this tutorial have been translated and updated from the book:

Neteler, M. (2000): GRASS-Handbuch. Der praktische Leitfaden zum Geographischen Informationssystem GRASS.[3] Geosynthesis 11, Geographisches Institut der Universität Hannover, 247 S. ISBN 3-927053-30-9 (A GRASS beginners tutorial in German language)

Search with CiteSeer[4] (published GRASS papers).

Notes

1. http://grass.itc.it/index.html
2. http://grass.itc.it/gdp/index.html#tutorials
3. http://grass.itc.it/gdp/handbuch/index.html
4. http://citeseer.nj.nec.com/cs?q=grass+gis

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