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GRASS GIS: A multi-purpose open source GIS

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ABSTRACT

The GIS software sector has developed rapidly over the last ten years. Open Source GIS applications are gaining relevant market shares in academia, business, and public administration. In this paper, we illustrate the history and features of a key Open Source GIS, the Geographical Resources Analysis Support System (GRASS). GRASS has been under development for more than 28 years, has strong ties into academia, and its review mechanisms led to the integration of well tested and documented algorithms into a joint GIS suite which has been used regularly for environmental modelling. The development is community-based with developers distributed globally. Through the use of an online source code repository, mailing lists and a Wiki, users and developers communicate in order to review existing code and develop new methods. In this paper, we provide a functionality overview of the more than 400 modules available in the latest stable GRASS software release. This new release runs natively on common operating systems (MS-Windows, GNU/Linux, Mac OSX), giving basic and advanced functionality to casual and expert users. In the second part, we review selected publications with a focus on environmental modelling to illustrate the wealth of use cases for this open and free GIS.

Software availability

- GRASS GIS software:
  - Free under the GNU GPL license and can be obtained from http://grass.osgeo.org/
- Operating System requirements:
  - MS-Windows XP or newer, MacOS X 10.4.10 or newer, recent GNU/Linux or a UNIX variant

1. Introduction

The capabilities of Geographic Information Systems (GIS) to integrate heterogeneous digital data into joint databases and to provide basic and advanced data analysis and visualization techniques led to the widespread use of GIS in public administration, industry and research. GIS has evolved to be used in a multitude of disciplines (Star and Estes, 1991; Foody, 2008) and has been deployed on systems ranging from grid computing to embedded systems in smartphones. Since the early days of GIS the market has evolved into the multi-billion dollar range (Goodchild and Haining, 2004). Two principal development paradigms are being followed: the open source and the closed source (often proprietary) development models. In the case of Free and Open Source Software, the source code is typically published under a Free Software license with end-user rights to run the program for any purpose, to study how the program works, to adapt it, and to redistribute copies including modifications.

The idea of Open Source Software may be as old as software development itself since code originating from universities and government laboratories has often been made available first in the public domain. In the 1990s a series of Open Source GIS software projects for both desktop and server systems was established in various GIS sectors, including software libraries for map reprojection and data format conversion, desktop GIS, Web mapping/Web GIS, spatial SQL databases, geostatistics, and metadata catalogues. In the field of environmental modelling, GIS technologies have been adopted in an early stage to capture and analyse spatial relations.

In the desktop GIS sector, the Geographical Resources Analysis Support System (GRASS, http://grass.osgeo.org) is one of the core components of the Open Source geospatial software stack.

GRASS is a multi-purpose Open Source GIS which can be used for geospatial data production, analysis, and mapping (Neteler and

Abbreviations: GRASS, Geographical Resources Analysis Support System; GIS, Geographic Information System; GPL, General Public License; OSGeo, Open Source Geospatial Foundation.

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Mitasova, 2008). It can handle 2D and 3D (voxel) raster data, includes a topological 2D and 3D vector engine with SQL-based attribute management, and vector network analysis functions. The database backend may be chosen from a number of popular alternatives. Furthermore, GRASS offers many spatial modelling algorithms, 3D visualization, as well as image processing routines pertaining to LiDAR and multi-band imagery. GRASS integrates well with other Open Source and proprietary software packages for geostatistical analysis, cartographic output, and Web GIS applications (Neteler et al., 2008). Along with a textbook (Neteler and Mitasova, 2008), a rich data set of free geospatial data has been published as a ready-to-use GRASS database as well as in standard GIS formats.

This paper seeks to provide some background information about the unique history of the GRASS GIS project, to illustrate the current features of the software, and to review selected GRASS applications published in the literature.

2. Background

In the 1980s, GRASS was the earliest Open Source GIS to reach production status and the first to support both raster and vector data models. Development began in 1982 by the United States Army Corps of Engineers (Construction Engineering Research Laboratory, CERL) with software distributed through academic and public administration channels. In the early 1990s, CERL created the Open GRASS Foundation which evolved into the Open GIS Consortium (OGC, today known as the Open Geospatial Consortium). The discontinuation of GRASS development by CERL in 1996 led to the formation of the international GRASS Development Team in its present form.

Originally published as public domain software, the license of GRASS was changed in 1999 to the GNU General Public License (GPL, see http://www.gnu.org), a popular Free Software license (Mitasova and Neteler, 2004). In 2006, the GRASS project became a founding member of the Open Source Geospatial Foundation (OSGeo, http://www.osgeo.org), and, through this, it holds today formal membership in a not-for-profit legal entity. Acceptance to OSGeo depends on a successful project incubation process which includes a detailed source code audit to identify any license incompatibilities in the code. This incubation process also confirms that the project is supported by a healthy community, including validation of the rules and processes governing the project's management. The project's infrastructure was shifted to OSGeo in order to establish a centralized new home for its website, Wiki help system, source code repository, community add-on module repository, and integrated bug tracking system.

Through the use of the GPL, GRASS may be installed and used without restriction in any commercial or non-commercial environment at no cost. Further benefits include the possibility to give the software along with course material legally for free to students in academic environments, e.g. on personalized USB memory sticks or for download. Additionally, and in contrast to most proprietary GIS software packages, GRASS GIS is portable, that is, it can be operated on various computer operating systems (GNU/Linux, Mac OSX, and MS-Windows operating systems are all officially supported). While Open Source Software licensed under the GPL can typically be freely downloaded from the Internet, it can be nonetheless used without restriction in for-profit commercial contexts and sold for profit as long as the terms of the GPL are fulfilled. In-house modifications and extensions can be kept private – the sharing of source code does not apply to data produced with it and applies only when redistributing the software. For example, GRASS can be used to produce value-added products taking advantage of its processing capabilities, or GRASS can be embedded into service chains as the GIS backend for Web Services.

The GPL further ensures that end-users can fully study, audit, modify, and extend the underlying algorithms and methods for this and any future version of GRASS. The GRASS project follows a typical Open Source development paradigm, with the source code being maintained in a public repository by a group of both paid and volunteer developers. Each change is subject to public peer review of code style, functionality, and quality. For end users, this development model provides highly interoperable and quality software at no cost. This approach is both flexible and immune to single vendor lock-in. In a scientific context, the reproducibility of results and quality assessment of methods is greatly facilitated since full access to the underlying algorithms is guaranteed. Substantial parts of GRASS have been developed by scientists and are based on published methods and concepts. Together with its many years of active deployment, it is this transparency which allows for the rigour of critical review and the quality assurance, upon which credibility of GRASS is founded. References to relevant literature are provided in the software documentation where appropriate. Since the GRASS community is a highly responsive environment, new functionality, e.g. an only recently published algorithm or method, can be implemented immediately in the development version or as an add-on, but has to undergo extensive testing and quality control before it will be available in the next official stable release.

3. Software capabilities

GRASS GIS 6.4.1, the current stable release, is the result of more than 9000 software enhancements and fixes with respect to the previous stable release 6.2.3. All changes are tracked in a public source code repository, along with a real-time notification system through email, IRC postings, and an automated and annotated online change log (Antoniol et al., 2003; Di Penta et al., 2005). Based on this, instant peer review is performed by a group of developers and other interested parties. GRASS is written in POSIX-conforming ANSI C with some functions written in the C++ and Python programming languages.

The recently published version 6.4 release offers two highly visible developments to the user experience, including a new modern Graphical User Interface (GUI) with an integrated location wizard (to define the project database and projection parameters), vector digitizer, SQL query builder, attribute editor, model builder, 3D view mode, and georeferencing tool including full native support for Microsoft Windows (2000, XP, Vista, and Windows7). The new native GUI is written in the Python programming language using the wxPython toolkit (Landa et al., 2008). As before, UNIX based platforms (GNU/Linux, Mac OSX, BSD, etc.) continue to be actively supported, as the source code base is portable. In addition, a first mobile solution for operating GRASS on handheld devices with real-time support through Wifi and voice control was demonstrated in (Stankovic et al., 2004). The graphical user interface and messages have been fully or partially translated into over 20 languages, including numerous European, Arabic, Japanese, Vietnamese, and other East Asian languages (Masumoto et al., 2005).

An extensive set of map projections and geodetic datums are supported with the ability to select interactively from standard map projections, to define custom parameters, to take projection parameters directly from georeferenced input data, or to select projection identifiers from the standard EPSG projection database (http://www.epsg-registry.org). GRASS expands on the pioneering PROJ.4 library (http://proj.osgeo.org) for much of this support and includes a number of georeferencing wizards and reprojection tools. Furthermore, some shortfalls in the current PROJ.4 concept for geodetic datum handling are overcome by internal extensions. The concept of the GRASS project database (known within the software as "locations", see Fig. 1) employs a strict single-location/