*Transactions in GIS*, 2004, 8(2): 145–154

# Guest Editorial

# GRASS as Open Source Free Software GIS: Accomplishments and Perspectives

## 1 Introduction

Over the past decade Geographic Information Systems (GIS) have entered many new disciplines and have become part of general computational infrastructure. Therefore it is not surprising that geoinformation technology is also being developed within the Open Source and Free Software community, well known for its GNU/Linux system. The concept of "Free Software" was first defined by Richard M. Stallman in the form of four freedoms:

- The freedom to run a program, for any purpose.
- The freedom to study how the program works, and adapt it to your needs. Access to the source code is a precondition for this criterion.
- The freedom to redistribute copies.
- The freedom to improve the program, and release your improvements to the public, so that the whole community benefits. Access to the source code is a precondition for this criterion as well.

Free Software is a matter of liberty, not price (Free Software Foundation 2002). The word free is used here as in "free speech", not "free lunch". To support the Free Software concept Richard M. Stallman conceived the GNU-Project in 1983 and a year later he created the Free Software Foundation. The license of the GNU-Project, the GNU General Public License (GPL) not only grants the four freedoms described above, but it also protects them. Under GPL the software can be modified and distributed, but its code, including the modifications must remain open. Because of this protection, GPL is the most widely used license for Open Source and Free Software nowadays (see more about Open Source and Free Software, their philosophy and differences at the respective web sites of the Open Source Initiative 2002 and the Free Software Foundation 2002).

Full access to the source code is particularly important for GIS because the underlying algorithms can be complex and can greatly influence the results of spatial analysis and modeling. To fully understand the system's functionality, it is important to be able to review and verify the implementation of a particular function. While an average user may not be able to trace bugs within a complex source code, there is a number of specialists willing to test, analyze and fix the code. The more sophisticated users can modify the existing code for their specific applications rather than having to write a new code from scratch. The different backgrounds and expertise of these developers contribute to faster and more effective software development. Over the past few years several Open Source and Free Software GIS and GPS projects have been implemented. Most of

© Blackwell Publishing Ltd. 2004. 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

them can be found at the "FreeGIS Project" web site (Reiter 2002). These projects play an important role in adaptation of GIS technology by stimulating new experimental approaches and by providing access to GIS for a wide spectrum of users.

This special issue of *Transactions in GIS* is devoted to the Open Source and Free Software GIS – GRASS User's Conference 2002, held in Trento, Italy, in September 2002. This was the first international GRASS user's conference with participants from 22 countries and 6 continents, reflecting the global distribution of developers and users, as is typical for Free Software projects.

## 2 GRASS GIS Evolution

GRASS was developed during the period 1982–1995 by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) in Champaign, Illinois, to support land management at military installations (Westervelt 1991, Shapiro et al. 1993, Goran 2002). During those years the open nature of GRASS attracted many contributions that CERL provided in the releases. Since the late 1980s coordination of GRASS development was handled by the GRASS Inter-Agency Steering Committee (GIASC), composed of managers representing several participating universities and federal agencies such as the National Park Service, Soil Conservation Service, and Department of Defense. As the commercial GIS vendors developed better raster-based capabilities, suitable for supporting natural resource management, GRASS use began dropping. Commercial GIS vendors also pushed for the cessation of funding on the grounds that the government should not be competing with the commercial sector. In response to the changing climate, CERL transferred GRASS to a new non-profit organization called the Open GRASS Foundation (OGF), which continued GRASS distribution, operation of GRASS User Conferences, and publication of *GRASSClippings*, the GRASS newsletter. The foundation later re-focused on interoperability, adopted a new name (Open GIS Foundation) and became a Consortium (OGC, Gardels 1993). CERL ceased its official sponsorship of GRASS and in the following transition period GRASS lost most of its support and users, who moved to off-the-shelf proprietary technology (Figure 1).

After forming a new development team in 1997, the turning point in the recent GRASS history was the adoption of GNU GPL in 1999. By this GRASS has embraced

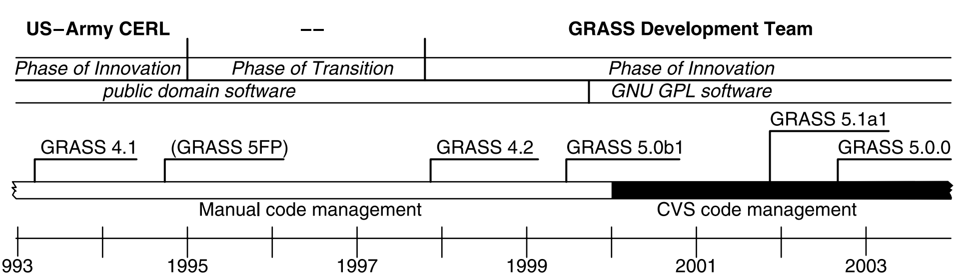


**Figure 1** Different GRASS development phases can be identified during the last ten years. Several major software releases were published first in the public domain, and later under the GNU GPL license. Code management is automated through a CVS server since 2000

© Blackwell Publishing Ltd. 2004

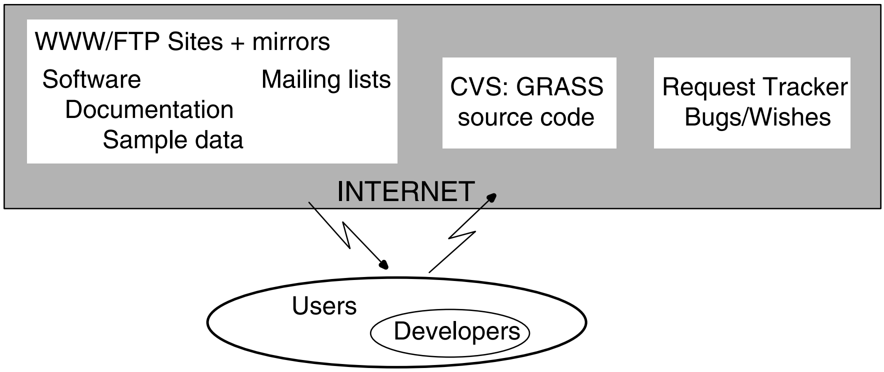


**Figure 2** Internet based GRASS development model

the Free Software philosophy (Stallman 2001, FreeGIS Team 2002). Establishment of a CVS (Concurrent Versioning System) server in December 1999 by Intevation GmbH, has provided a professional, automated environment for code management, crucial for such a huge and complex code base. The Internet has played a major role in the GRASS development and distribution, starting with the GRASS 4.0 release in 1991, by making it available to users all over the world. The Internet continues to be a core technology for GRASS development coordination and user support (Figure 2).

It appears that GRASS has successfully survived many years without official institutional or industry support and found its place in the Open Source and Free Software community. It has a critical number of developers and users, growing support infrastructure (distribution sites, mailing lists, literature, courses, national user meetings), and now the first international conference, since it has been released under GNU GPL.

## 3 Current GRASS Development Model

The GRASS development model is embedded in the Open Source and Free Software movement and style and uses well known tools for code management and dissemination (Figure 2). The main components of the development and software maintenance are built on top of a highly automated web-based infrastructure, sponsored by ITC-irst (Center for Scientific and Technological Research, http://grass.itc.it) in Trento, Italy, and numerous other worldwide sites where the code base is mirrored. The most important task – coordination of development – is accomplished through the developer mailing-list. The emphasis is on two major efforts:

- Stable releases for routine users with a focus on reliability; and
- Development and maintenance of the experimental environment for implementation and testing of new data structures, code organization, and functionality.

The GRASS development team can be considered as "council type" as opposed to Raymond's "bazaar type" and "cathedral type" development models (Raymond 1997). A limited, but open group takes decisions about design and implementation. Decisions on code submission, substitution or deletion are taken in consensus, usually in a "if-no-objections" mode. The developers are also advanced GRASS users who are familiar with

© Blackwell Publishing Ltd. 2004

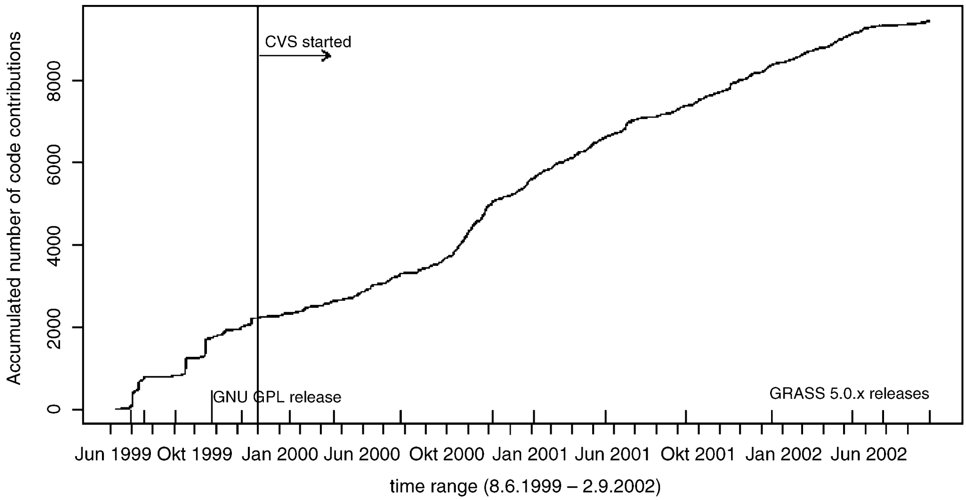


**Figure 3** The graph shows the accumulated number of code submissions to GRASS 5.0.0 from 8th June 1999 to 2nd September 2002 (based on history files and CVS ChangeLog). The first month were dedicated to source code portability enhancements. After switching to CVS a slight curve depression can be observed, possibly due to the fact that the developers had to get used to CVS management. The submission decrease from July 2002 onwards indicates that the code has been considered as stable (official stable release 5th September 2002)

most of the system's functionality and view the system both from the developer's and a user's standpoint. This simplifies communication and improves the user support. The code development coordinator takes care of quality issues: s/he supervises, as much as possible, the submission of portable ANSI-C source code, documentation updates, s/he often tests changes, explains the code structure to newcomers, etc. Supervision of code quality and consistency is among the most important tasks. The coordinator also plays a role in "connecting people together" who do not know each other but share interests, leading to faster code development.

Bugs are reported through the on-line bug-tracking system. The response time for bug reports is very short: bugs are often resolved within one or two days, and the updates are directly available through CVS (similar to other Free Software projects). A thorough study of this issue may be interesting in terms of software engineering and code evolution, particularly with regard to the long time span of GRASS development.

Various tools are used for code management and dissemination: GNU/Linux, the Apache web server, wu-ftp, rsync mirror software, Mailman mailing list software (currently eight GRASS related lists are hosted at ITC-irst), CVS, GNU gcc compiler and others. A notification mailing list distributes the source code differences as sent from the CVS server to several developers for verification. Figure 3 shows the accumulated number of code submissions to the CVS server for two years of GRASS 5.0.0 development (from Beta1 in 1999 to the stable release 2002). The submissions curve shows some "stairs" in the pre-CVS times because submission dates were only recorded by sub-release versions. Later, the CVS ChangeLog history provides precise information about code changes. The FreeGIS Project plays an important role by providing this CVS server and by monitoring compliance with Free Software GPL.

© Blackwell Publishing Ltd. 2004

Several GRASS versions are available, but not every version is intended for every user. The Linux kernel numbering scheme of releases is currently being adopted. All *major.even.minor* versions are intended for the general user and considered as stable (e.g. 5.0.x), while *major.uneven.minor* are development, experimental versions (5.1.x).

In summary, it can be stated that after more than three years the GNU license is continuously attracting new developers. The management of GRASS in CVS has stabilized the development and taken unnecessary administrative workload from various shoulders. The additional management tools (such as Request Tracker, mailing lists, etc.) support one of the most important issues in Free Software development: communication.

## 4 Evolution of GRASS Functionality

While most of the GIS software development has evolved around the need to automate the map drawing process, GRASS has been focused, from the very start, on spatial analysis needed for land management applications. As a cost effective land management tool, GRASS was designed with raster data analysis at its core, further enhanced by basic image processing and vector capabilities aimed at supporting cartographic output. Raster-based spatial analysis continues to expand. Floating point raster data support in GRASS5.0 improves the analysis and modeling with continuous fields (e.g. Bonk and Bishop 2002), import capabilities based on the GDAL library (Warmerdam 2002) increase efficiency of working with external raster data. Raster modules are being continuously enhanced and new ones are being added, for example, to support wavelet analysis (Zatelli and Antonello 2002), irradiation modeling (Šúri and Hofierka 2004, this issue) and hydrologic and sediment transport simulations (O'Donnell 2002; Hofierka et al. 2002a).

GRASS has served as a research environment for exploration of new algorithms, approaches and applications. Land management related research supported significant GRASS development with new modules added as by-products of these projects. Pioneering work has been conducted in a number of areas, such as coupling of environmental and physical process models with GIS, or visualization and 3D dynamic GIS (Mitasova et al. 1995, Figure 4). Port of *nviz* to OpenGL has opened the use of GRASS visualization to non-SGI platforms as reflected in a number of conference papers (e.g. Zatelli and

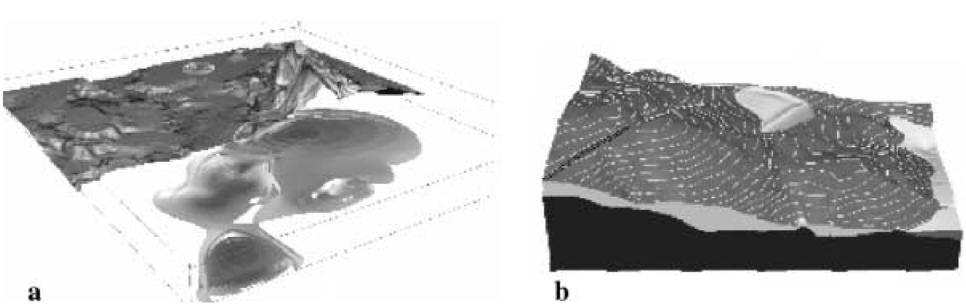


**Figure 4** Surface/volume processing and visualization: (a) prototype volume interpolation and visualization for groundwater pollution study (GRASS3D prototype 1993); and (b) visualization of multiple surfaces with cutting plane – comparison of terrain before and after construction (GRASS 5.0.0 *nviz*)

© Blackwell Publishing Ltd. 2004

Antonello 2002; Mitasova et al. 2002; Masumoto et al. 2004, this issue). The volume data support development continues within the experimental GRASS version available through CVS, as illustrated by the recent contribution of the volume interpolation and analysis module *s.vol.rst* (Hofierka et al. 2002b), modeling of evaporation processes by *r3.mapcalc* (Ciolli et al. 2004, this issue) and 3D geology models (Masumoto et al. 2004, this issue).

Image processing tools have been incorporated thanks to the strong raster data support. After a period of discontinuity new tools are under development such as automated image registration (e.g. Tipdecho 2002). Decision support tools have evolved from the early contributions such as B-infer (Bayesian expert system, Buehler and Wright 1991), to recent applications for flood management (Garcia 2004, this issue), or radar meteorology (Löwe 2004, this issue).

Besides the areas with a long history of development and applications, there is a number of new contributions reflecting the current advances in GIS technology:

- Ongoing implementation of a new, efficient, 3D multi-attribute vector architecture with RDBMS support (Blažek et al. 2002) creates opportunities to extend the GRASS vector capabilities to the level comparable with raster data processing and beyond;
- Development of *babyGRASS* for wireless and mobile GIS, e.g. using iPAQ and Zaurus handheld computers, opens possibilities to bring GRASS into the field (Stankovic et al. 2004, this issue);
- Several Web mapping applications and a Web interface provide online access to GRASS databases and tools by combining GRASS with other Open Source and Free Software tools, such as PHP, MapServer and PostgreSQL (Hess 2002; Masumoto et al. 2004, this issue; Neteler and Mitasova 2002);
- Support for modern mapping technologies is being added, such as LIDAR data processing and applications (Brovelli et al. 2004, this issue; Mitasova et al. 2002) and related support for processing of massive data sets (Toma et al. 2001);
- GRASS applications continue to expand beyond its traditional environmental and land management areas, for example, to geology (Masumoto et al. 2004, this issue), coast and sea (Saul et al. 2002, Mitasova et al. 2002), space (Frigeri et al. 2004, this issue), atmosphere (Ciolli et al. 2004, this issue), medical and epidemiological analysis (Furlanello et al. 1997, Rizzoli et al. 2002);
- Linkages to other Open Source and Free Software projects such as *gstat* or *R* statistical software (Bivand and Neteler 2000, Bivand 2002) continue to rapidly expand and strengthen the power of the Open Source and Free Software geospatial computing environment.

The increasing number and variety of contributions demonstrates that GRASS is a living system that builds upon its traditional fields in land management and environmental modeling and is expanding into new areas in response to the developments in mapping and geospatial technology.

## 5 The Need for Universal Access to Geo-Data

The 2002 summer floods in Central Europe that devastated many towns, affecting hundreds of thousands of people, confirm the need for detailed knowledge about terrain structure, flow directions and hydrologic conditions. Such information and related tools

© Blackwell Publishing Ltd. 2004

can be much faster and more efficiently developed if the necessary data are readily available to the public, especially for research.

Georeferenced data are an integral part of GIS. They are often generated at a significant cost to taxpayers by local and national governments. In the U.S., federal, state and local government agencies provide free-of-charge access to a wide range of geospatial data driven by a "vision of universal access" through the National Spatial Data Infrastructure (NSDI), GeospatialOne, and USGS National Map (USGS 2003) programs. In contrast to this vision, access to GIS data in Europe is usually restricted by financial or legal barriers. Comparison of geotechnology developments in the U.S. and Europe demonstrates that restrictions in the availability of georeferenced data slow down the development and limit the information available to citizens about their environment. As a work-around, scientists in Europe often use data from U.S. systems such as GPS (unfortunately, the upcoming European Galileo system, planned to be operational in 2008, might be partially encrypted) or the satellites monitoring the Earth surface (LANDSAT-7, TERRA ASTER/MODIS). While coastal and some state LIDAR data are available on-line in the U.S. (see, for example, NOAA 2002, State of North Carolina 2003), no free-of-charge high resolution elevation data are provided for European countries. The sole data available free-of-charge for Europe are low resolution U.S. governmental data sets such as GLOBE-DEM, GTOPO30, ETOPO5 and for selected areas 30 m elevation data derived from Stereo-ASTER channels. While the SRTM Shuttle Radar Topography Mission data were recently made available for the U.S., they are not yet available for Europe, Asia, South America or other parts of the world. According to a recent JPL announcement, they will not be available earlier than the end of 2003, even then probably not free-of-charge. In addition, there are no European climate data accessible without paying substantial amounts of money, while data for 11,000 stations distributed in non-European parts of the world can be downloaded from U.S. web sites (NCDC/NOAA). It is quite surprising that even the borders of several European countries are publicly unavailable, neither from the European Commission nor from the countries' governments.

Unfortunately only a few agencies have a clear, mandatory policy for releasing GIS research results in the form of surveyed and derived georeferenced data to the public. It is obvious, that except for the data critical to national security, the public which pays for the mapping and GIS activities should have easy access to basic spatial data such as elevation models, climate data, and vector data networks.

Data released to the public by governmental institutions, generated as research results or by private companies, need to be protected to keep the freedom of their usage. A license which protects universal access to modified geospatial data, in a similar way as GPL protects access to the modified code, does not yet exist. Therefore we believe that there is an urgent need for the development of a *Free GeoData License* (called "FGDL") in the spirit of GNU GPL. A similar proposal was made for data in bioinformatics (O'Reilly 2001).

## 6 The Future of GRASS

As Open Source and Free Software is being increasingly implemented in mainstream systems (International Institute of Infonomics and Berlecon Research GmbH 2002, Markoff 2002) the use of related geospatial tools is expanding as well. We envision that

© Blackwell Publishing Ltd. 2004

GRASS will remain a general-purpose GIS, but its improved structure, higher level of abstraction and modularity should support local adaptation for specific applications. With a modularized system (in terms of code organization, internal interfaces, well defined API, etc.) the GRASS modules may be implemented in different environments and stimulate further experimentation. We can expect initiatives leading to several possible paths of GRASS evolution (in the Darwinian sense, with the successful ones growing and those less successful dying out):

- GRASS as *GIS for everybody* (Open Source and Free Software GIS equivalent to existing proprietary systems based on free and/or commercial interfaces). This direction may be hard to accomplish with a relatively small number of developers; however, GRASS may grow in this direction "naturally" as more complex applications need efficient basic tools;
- GRASS as a *geospatial research environment* which provides solid core functionality and encourages experiments and innovation;
- GRASS as a *professional, general purpose GIS*, with reliability and stability as the most important issues;
- GRASS as a *system of modules* which can be plugged into specialized applications or devices to provide geospatial processing tools;
- GRASS as *something as of yet unexplored*, because there is always a possibility of a completely new and unexpected direction stimulated by new technology developments and ideas.

While GRASS is still catching-up for the years of stalled development, a lot of effort is currently focused on creating a free environment which stimulates the development of a new generation of tools, algorithms, data structures and applications. Open Source and Free Software infrastructure offers an excellent opportunity for efficient development of a robust and reliable GIS code with freedom for everybody to run, study, redistribute and improve it for the benefit of the entire community.

## Acknowledgments

The support by the National Research Council and U.S. Army Research Office is gratefully acknowledged. Markus Neteler was partially supported by the FUR-PAT Project WEBFAQ. We also thank Jim Westervelt for valuable input and review.

Helena Mitasova
*Department of Marine, Earth and Atmospheric Sciences*
*North Carolina State University*

Markus Neteler
*ITC-irst, Centre for Scientific and Technological Research*
*SSI Division, Trento, Italy*

## References

Bivand R 2002 Development of the GRASS/R interface: GIS and statistical data analysis. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

© Blackwell Publishing Ltd. 2004

Bivand R and Neteler M 2000 Open Source geocomputation: Using the R data analysis language integrated with GRASS GIS and PostgreSQL data base systems. In *Proceedings of the Fifth Conference on Geo-Computation*, University of Greenwich (available at http://reclus.nhh.no/gc00/gc009.htm)

Blažek R, Neteler M, and Micarelli R 2002 The new GRASS 5.1 vector architecture. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference, Trento, Italy, 11–13 September 2002*, University of Trento, Italy

Bonk R and Bishop M P 2002 Scale-dependent geomorphometric analysis for glacier mapping at Nanga Parbat. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Buehler K and Wright J 1991 Bayesian reasoning shell for land management: I, Structure and Function. *Journal of Computing in Civil Engineering* 5: 267–82

Free Software Foundation 2002 The Free Software Definition. WWW document, http://www.gnu.org/philosophy/free-sw.html

FreeGIS Team 2002 The FreeGIS Project. WWW document, http://www.freegis.org/

Furlanello C, Merler S, and Chemini C 1997 Tree-based classifiers and GIS for biological risk forecasting. In Morabito F (ed) *Advances in Intelligent Systems*. Amsterdam, IOS Press: 316–23

Gardels K 1993 Defining Open GIS: An introduction to the Open Geodata Interoperability Specifications (OGIS). *GRASSClippings, The Journal of Open GIS* 7(2): 7–13

Goran W 2002 *Foreword*. In Neteler M and Mitasova H *Open Source GIS: A GRASS GIS Approach*. Boston, MA, Kluwer: xxi–xxiii

Hess S 2002 GRASS on the Web. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Hofierka J, Mitasova H, and Mitas L 2002a GRASS and modeling landscape processes using duality between particles and fields. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Hofierka J, Parajka J, Mitasova H, and Mitas L 2002b Multivariate interpolation of precipitation using regularized spline with tension. *Transactions in GIS* 6: 135–50

International Institute of Infonomics and Berlecon Research GmbH 2002 Free/Libre and Open Source Software: Survey and Study. WWW document, http://www.infonomics.nl/FLOSS/report/index.htm

Markoff J, 2002 Microsoft and Free Software at the same show? It's true. *New York Times* (August 10) (available at http://www.nytimes.com/2002/08/10/technology/10LINU.html)

Mitasova H, Drake T, Harmon R, Hofierka J, and McNinch J 2002 Spatio-temporal monitoring of evolving topography using LIDAR, Real Time Kinematic GPS and sonar data. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Mitasova H, Mitas L, Brown W, Gerdes D, Kosinovsky I, and Baker T 1995 Modeling spatially and temporally distributed phenomena: New methods and tools for GRASS GIS. *International Journal of Geographical Information Systems* 9: 433–46

NOAA 2002 LDART: Lidar Data Retrieval Tool. WWW document, http://www.csc.noaa.gov/crs/tcm/about_ldart.html

Neteler M and Mitasova H 2002 *Open Source GIS: A GRASS GIS Approach*. Boston, MA, Kluwer

O'Donnell S 2002 Weather Radar enhanced flash flood forecasting. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Open Source Initiative 2002 The Open Source Definition. WWW document, http://www.opensource.org/docs/definition.php

O'Reilly T 2001 In the trenches: What's next for Linux and Open Source? *Linux Magazine* (available at http://www.linux-mag.com/2001–10/trench_01.html)

Raymond E 1997 The Cathedral and the Bazaar. WWW document, http://www.ccil.org/˜esr/writings/cathedral-paper.html

Reiter B 2002 How GRASS' development reflects Free Software history and what to expect next. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy


© Blackwell Publishing Ltd. 2004

Rizzoli A, Merler S, Furlanello C, and Genchi C, 2002 Geographical information system and bootstrap aggregation (bagging) of tree-based classifiers for lyme disease risk assessment in Trentino, Italian Alps. *Journal of Medical Entomology* 39: 485–92

Saul C, Bonacito C, Costantini M, and Spoto M 2002 Sea-bed classification and sea-bottom mapping with GRASS in the R.N.M.M. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Shapiro M, Westervelt J, Gerdes D, Larson M, and Brownfield K R, 1993 *GRASS 4.1 Programmer's Manual*. Champaign, IL, U.S. Army CERL Technical Report

Stallman R, 2001 Free Software: Freedom and Cooperation. *Transcript of a speech delivered at New York University in New York* (available at http://www.gnu.org/events/rms-nyu-2001-transcript.txt)

State of North Carolina 2003 North Carolina Flood Mapping Program. WWW document, http://www.ncfloodmaps.com/

Tipdecho T 2002 Automatic image registration between image and object spaces. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

Toma L, Wickremesinghe R, Arge L, Chase J S, Vitter J S, Halpin P N, and Urban D 2001 Flow computation on massive grids. In *ACM Symposium on Advances in Geographic Information Systems* (available at http://citeseer.nj.nec.com/toma01flow.html)

USGS 2003 The National Map. WWW document, http://nationalmap.usgs.gov/index.html

Warmerdam F 2002 GDAL: Geospatial data abstraction library. WWW document, http://www.remotesensing.org/gdal/

Westervelt J 1991 GRASS Updates. *GRASSClippings, Geographic Resources Analysis Support System Newsletter* 5(2): 2

Zatelli P and Antonello A 2002 New GRASS modules for multi-resolution analysis with wavelets. In Benciolini B, Ciolli M, and Zatelli P (eds) *Proceedings of Open Source Free Software GIS – GRASS Users Conference*, University of Trento, Italy

© Blackwell Publishing Ltd. 2004