

TerraLAB – Using Free Software for Earth System Research and Free Software Development

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***Abstract.** This paper presents a success case of using free software platforms for research and free software/model development for Earth System studies. We describe the technologies and methodologies used for this purpose. We also discuss the main results, challenges and solutions found on constructing a sustainable free software project which should serve as a foundation for the development of state-of-the-art environmental models and researches. The TerraME software have been used for answer national issues about the Brazilian Amazonia occupation through the analysis of computer generated scenarios, which are produced by biophysical and socioeconomic complex system simulations integrated with real-world geographical databases.*

1. Introduction

The intensification of environmental changes caused by anthropogenic activities has led to the use of several software platforms for the modeling and simulations of human-environment interactions. However, due to the lack of an established theory on this matter and to the fact of nowadays modeling platforms have not been specifically designed for this purpose, they do not satisfy the whole requirements involved in this task. This fact motivated INPE (National Institute for Space Research) and UFOP (Federal University of Ouro Preto), in a mutual effort, to launch and fund the *TerraLAB - Laboratory for Earth System Modeling and Simulation*, which mission is to design and develop a free environmental modeling platform. The TerraME engine provides data-structures and services for representing and simulating a wide variety of spatially-explicit models of dynamic geographical phenomena. The models are integrated to geographical databases which are fed with real-world data acquired by remote or grounded sensors, field works, census campaign or literature reviews, allowing for very

realistic simulations and scenarios analysis. In the last four years, the TerraME have been used for the development of Land Use and Cover Change (LUCC) models which address the Brazilian Amazon issues [Aguiar et al. 2007] [Moreira et al. 2009], for simulation of fire propagation at national reserves [Almeida et al. 2008], social simulations [Andrade et al. 2009] and others.

This paper presents the main challenges, solutions and results obtained in the development of the TerraME environmental modeling platform. Besides the difficulties brought by the complex requirements of this application domain, from the software production point of view, the main challenges were to start and to promote the project in the first years; and to make the project strong and sustainable along the years so that, in the future, it might become a foundation for environmental studies. To overcome these challenges, we have had to specify and implement a low cost software development environment in the TerraLAB. This environment should provide essential services for project and software version management, for computer aided software specification, for C++ source code editing, compilation and debugging, and for source code and project documentation. The TerraME development team has been trained on this environment. Funds have been obtained from government programs and institutions. Partnerships between institutions have been established to share resources, research projects and people. Graphical interfaces and a script language have been integrated with the TerraME engine in an attempt to make it easier to use and, this way, to enlarge its user community. A TerraME engine stable version and some components currently in development, as well as some environmental models, are the main results from this activities.

The article is organized as follows. Section 2 presents the TerraLAB mission and research/development infrastructure. Section 3 gives a brief description of the process used in developing research/model/software. Section 4 presents some of the technologies used to develop and support the TerraLAB activities. Section 5 shows some of the software projects currently in development at TerraLAB. Final considerations are done in section 6.

2. The TerraLAB

The *TerraLAB* mission and goals are: (a) The development of spatially explicit dynamic models to better understand the functioning of earth systems; (b) The implementation of environmental models in the form of computing systems which provide prognoses about the future behavior of the Earth systems, and which can be used to support decision making about human and institutional actions; (c) The design and implementation of geo-technologies that support the development of models for earth systems, for example, geographic information systems (GIS); (d) Serve as an education and research platform for undergraduate and postgraduate courses; (e) The training of specialists in spatial dynamic modeling; and (f) The dissemination of technologies developed and used by the laboratory. These goals are addresses by the four kinds of products developed by the TerraLAB laboratory: (1) software projects; (2) environmental models, (3) undergraduate and postgraduate courses and (4) techno-scientific publications.

Development and research activities are carried out through partnerships with public and private institutions. A professor doctor coordinates the day-by-day

laboratory operation and manages the projects in development. A multidisciplinary team of doctoral, master and undergraduate students actively participates in the development of products. Students have advisers at different institutions which have different vocation, this way allowing for interdisciplinary advances. Team members are volunteers writing academic dissertations or are project members who receive scholarship from Brazilian research funding agencies or programs, like the Minister of Science Network for Research on Environmental Modeling at Amazônia, GEOMA [<http://www.geoma.lncc.br>].

The TerraLAB hardware infrastructure has 6 dual boot development workstations running Windows and Linux. All software products are target to both operating systems. Furthermore, 2 simulation servers, 1 network and web server (DHCP, DNS, Apache, DokuWiki) and 1 file and database server (MySQL, CVS, Samba) provide the necessary services for the management and development of the projects. The openSUSE (<http://ww.opensuse.org/>) Linux distribution is used.

3. The Development Process

The development of the TerraLAB products occurs according to the cyclic and incremental process illustrated in Figure 1. At the end of each conception, design, implementation and test cycle, an improved version of the product is produced.

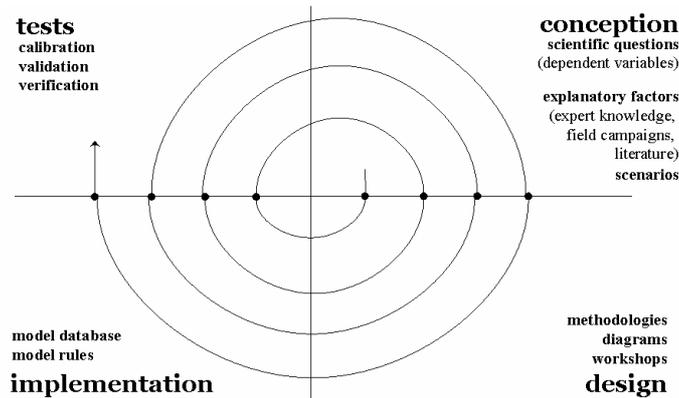


Figure 1. Software and Models development process

4. Technologies

The TerraLAB since its conception uses ideas, concepts and solutions widely distributed by the free software community. Geo-technologies like the geographic information system Spring [Câmara et al. 1996], the spatial data viewer TerraView (www.dpi.inpe.br/terraview), the C++ GIS library of classes and functions TerraLib [Câmara et al. 2000][Câmara et al. 2008] and the aRT [Andrade 2006] extension for the R statistical software [Ihaka and Gentleman 1996], are used for data acquisition, storage, visualization and analysis during the construction of environmental models and study cases.

For model development the TerraME framework has been integrated with the Lua programming language [Ierusalimschy et al. 1996], providing a high level modeling language for the TerraME users. A MySQL (www.mysql.com) database server is used to store model input and output data.

For software development at Windows and Linux operating systems, we use the C++ free compilers and tools available on the web, including the MinGW (*Minimal GNU for Windows*) package. The Eclipse Platform (www.eclipse.org) is used as integrated development environment. The Bugzilla (www.bugzilla.org) software is been used for bug tracking. A free CVS (*Concurrent Version System*) server is use to control the versioning of model and software source codes. A free version of the QT (www.qtsoftware.com) C++ library is used for graphical user interface development.

The entire software development process is documented through a wiki tool. The Apache (ww.apache.org) web server and the DokuWiki (www.dokuwiki.org) software are used for project documentation and for information sharing on the web. According to Schons et al. (2007), a wiki tool allows create an interactive space to have the management of knowledge, serving as a means of access to collaborative learning and integration between the people involved.

5. Software Projects

In this section, some of the software projects currently in development at the TerraLAB laboratory will be presented.

5.1. TerraME

TerraME is a development environment for spatial dynamic modeling which supports the concepts of Nested Cellular Automata (nested-CA) [Carneiro 2003]. The key part of the TerraME development environment is the *TerraME interpreter*. It reads a program written in the TerraME modeling language – a Lua [Ierusalimschy et al. 1996] language extension, interprets the source code, and calls functions in the TerraME Framework. This framework is a set of modules written in C++ that provides functions and classes for spatial dynamic modeling. It also links to a *TerraLib* [Câmara et al. 2000] spatial database. The *TerraView* application displays the results of simulation.

5.2. TerraME Graphical Interface for Modeling and Simulation

The TerraME GIMS - *Graphical Interface for Modeling and Simulation* [Lima et al. 2008] is a graphical interface that allows the specification of TerraME models through diagrams. It aims to create a new and higher level of abstraction for model specification, reducing the TerraME learning curve for those users unfamiliar with programming techniques and algorithms. This way, the TerraME GIMS allows modelers to focus on solving application domain problems instead of focus on the computational representation of these problems. This TerraME component is being developed as a set of plug-ins for the Eclipse platform [Eclipse 2006].

5.3. TerraME High Performance Architecture

The TerraME HPA - *High Performance Architecture* is a distributed version of the TerraME engine which aims to offer to the TerraME users the benefits of the aggregated processing and storage power of a computer network. The main idea is to provide high performance without the necessity of changes in the model source code. All the distribution activities are carried out automatically by the architecture.

5.4. TerraME Observer

The TerraME Observer provides services and features for analysis and visualization of environmental models during their execution, allowing the modelers to monitor in real time, through graphics and maps, the dynamics of the model under study.

5.5. TerraME GIS Integration

The TerraME presents a restriction to be strongly coupled to the library TerraLib. Thus, this project aims to reduce this current restriction allowing TerraME to be integrated with others GIS libraries and systems. Also, this project aims to improve the current integration so that the modeler could take greater advantage of the spatial-temporal data functions and types provided by the TerraLib library.

6. Final Considerations

The use of free technologies is growing in Brazil and in the world. The Brazilian government has invested particularly heavily on expanding the adoption of the free technologies available. The *Free Guide - Reference for Migration to Free Software Federal Government* [Guia Livre 2004] points out the socialization of knowledge as the main motivation for the use of free software. Other reasons are the level of safety provided by free software, the elimination of the compulsory upgrades required proprietary software, technological independence and the development of local knowledge. According to the Green Paper [Takahashi 2000] the maintenance of the sovereignty and of the autonomy of country depends on the education and scientific and technological knowledge it produces and holds.

For a long time the geo-informatics field was dominated by high cost and proprietary tools and formats. Despite of the current enormous use of proprietary software, there are several initiatives toward free GIS development (www.freegis.org, opengeospatial.org, opensourcegis.org). Câmara et al. (2002) highlight the importance of partnerships and cooperation between institutions in projects of this nature, as well as importance of the involvement of the potential user community from the very beginning stage of the development process.

Meeting with these initiatives, as presented throughout the article, the TerraLAB has been using and working on the development of free technologies. The TerraLAB provides a platform for research and for free software/model development for Earth System studies.

7. References

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