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The Amazon Deforestation Monitoring System

A Large Environmental Database Developed on TerraLib and PostgreSQL

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Abstract

Brazil's National Institute for Space Research and the Foundation for Space Science, Technology and Applications developed a complete monitoring system, based on TerraLib open source technology[26] (Camara, G., et al., 2000), in order to map and calculate the annual deforestation rates in the Brazilian Amazon. TerraLib implements the archiving of geographic vector and raster data, on a variety of proprietary and non-proprietary DBMS, including PostgreSQL. TerraLib supports methods for image and vector data processing and analysis. A client application, named TerraAmazon, was developed using C++ and the free graphic user interface toolkit QT (version 3), which runs on LINUX or Windows machines. The data is managed by PostgreSQL version 8.2, running on a LINUX Server. The application manages all data work flow, gathering around 600 satellite images, pre-processing, segmenting and classifying these images, for further human interpretation and edition, on a concurrent multi-user environment. The database stores approximately 2 million complex polygons and 20 gigabytes of full resolution satellite images are added every year, using TerraLib pyramidal resolution schema. A Web site is provided for visualization and analysis of full resolution data, using the TerraLib PHP extension and TerraLib OGC WMS server.

Introduction

Brazil conducts a large environmental project to monitor deforestation in the Amazon biome using satellite data. Every year a deforestation map and the rate of yearly deforestation are produced and made public over the Internet by Brazil's National Institute for Space Research ("Instituto Nacional de Pesquisas Espaciais" – INPE). The Brazilian Amazon biome covers an area of 4.7 million square kilometers. Given this huge area, the task is very demanding. At every year a complete coverage of the region by satellite images, with 20 to 30 meters resolution, are acquired, automatically processed and analyzed by remote sensing specialists.

The final deforestation data product has cartographic precision suitable for a 1:250,000 scale. This project is named PRODES – short for Legal Amazon Deforestation Project - started at the end of the 1980s, and has evolved from an analog interpretation process to a fully digital procedure. The current methodology was implemented in 2005 and its technical features are presented in this paper.

Before the new system became operational, deforestation maps were produced using SPRING, a free desktop image processing and geographic information system developed by INPE.[27] In order to produce the complete deforestation map, 229 independent databases, each one covering the area of one LANDSAT 5 satellite image were required. This methodology created a complex environment for management since each database was transferred from one workstation to another to be submitted to a specific process, involving dozens of specialists.

In addition to the complexity of the previous methodology, new requirements forced the Brazilian government in 2005 to improve the former methodology. The first new requirement was the need to introduce multi-satellite source, in order to guarantee data availability, even under a satellite operational interruption. Images from the 20 meter resolution CBERS (China Brazil Earth Resources Satellite) CCD sensor, 30 meter LANDSAT 5 images and 32 meter DMC (Disaster Monitoring Constellation) satellites images are now used. Figure 1 shows the satellite images used for 2005 deforestation mapping. The second requirement was the need for a fast data delivery, in order to create conditions to implement government policies to be applied earlier, before the next period of deforestation.

The use of CBERS images as the primary data source increases the number of images to 570 and the use of the previous methodology with independent databases would have created a yet more complex environment for data management. The solu-

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[26]TerraLib Library: http://terralib.org/
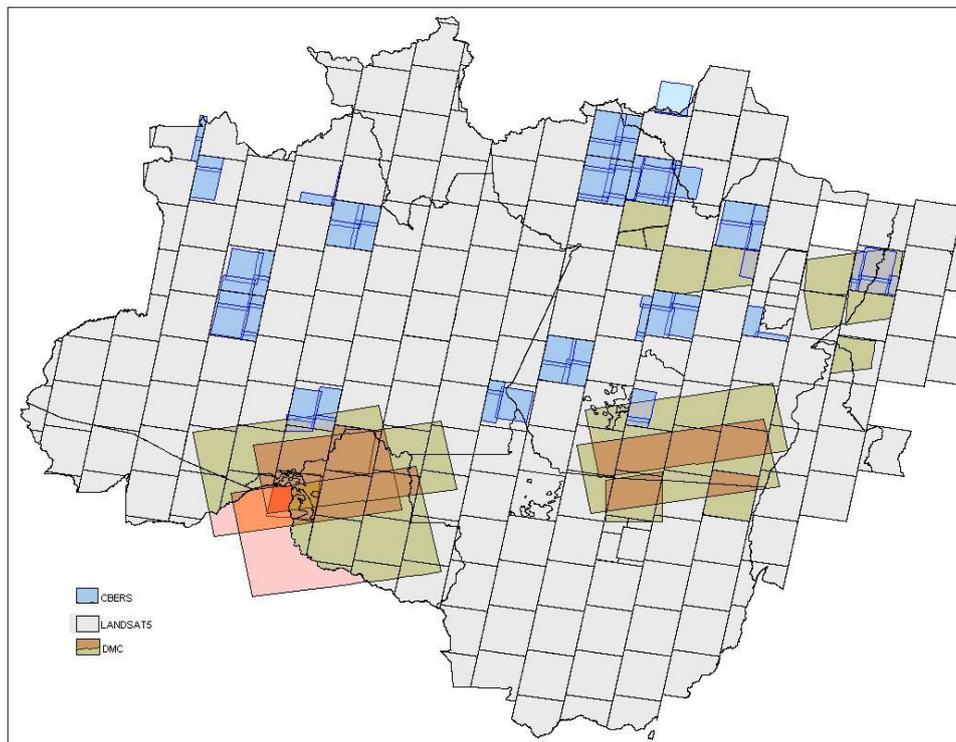[27]INPE SPRING project: http://www.dpi.inpe.br/spring

Figure 1: The 221 CBERS, 223 LANDSAT, and 18 DMC satellite images used in 2005

tion was to create a unique corporate database which is suitable for management of all data operations, in a distributed and concurrent environment.

The technology selected to achieve the project goals was TerraLib. TerraLib is an Open Source Library developed by INPE and distributed under GNU LGPL license.[28] TerraLib implements the storage of geographic vector and raster data, on a variety of proprietary and non-proprietary Database Management System (DBMS), including PostgreSQL. TerraLib implements methods for image and vector data processing and analysis. FUNCATE under contract with INPE developed the complete suite of computer programs to process all data and deliver the deforestation maps and annual rate, on a full open source environment. This suite of programs was named TerraAmazon.

Methodology

Deforestation and subsequent burnings occur in Amazon during a short period: the dry season, from July to September. After this season, it is virtually im-

possible to deforest, due to the high rates of precipitation. Based on this fact, the annual deforestation rate is calculated for the period between August 1st of the previous year and July 31st of the current year. The later date coincides with the end of the dry season for most part of the Amazon. In order to obtain the deforestation rate, images acquired during the dry season period are analyzed. The annual deforestation rate is estimated by interpolation, considering that deforestation occurs linearly during the dry season. In addition, deforested areas are estimated under regions covered by clouds, considering that the ratio of deforestation is the same in areas with and without clouds coverage. Detailed information of this method can be found at INPE's site.[29]

TerraAmazon manages all operations required by the deforestation project, in an interactive, distributed and concurrent environment using a corporate database. In order to take full advantage of TerraAmazon, the whole Amazon region is divided into cells and each cell is manipulated by only one remote sensing specialist at a given time.

Cells are created by partitioning the project extents using a geographic grid with 0.25 degrees dis-

[28]TerraLib Library: http://www.terralib.org
[29]Detailed information available online: http://www.inpe.br/prodes

tance between grid lines. Each remote sensing specialist can lock one or more cells to process using a long transactions schema. The expert manipulates one of these cells using image processing and vector edition tools available in TerraAmazon. The following steps are applied to each of these cells.

1. Import a TIFF image
2. Register image with reference image and save used control points
3. Audit image using reference image, and
4. If image is not approved then repeat from step 2
5. Create shade and ground images
6. If image has cloud coverage above a given threshold then
   (a) Classify image to extract regions with clouds
   (b) Convert regions to cloud polygons
7. Segment shade and ground images
8. Combine ancillary vectors (previous years deforestation, non forest, and hydrography polygons), segmentation polygons, and cloud polygons (if any)
9. Interpret and edit combined vectors to create new deforestation and cloud polygons
10. Audit resulting polygons. If not approved then return to 8; and
11. Disseminate results.

The image processing tools available in TerraAmazon are: TIFF format image file import, georeferencing based on control points, color composition and enhancement, mixing model analysis, segmentation, and classification.

For vector edition, TerraAmazon include: raster to vector and vector to raster conversion, vector elements edition that considers snap and topology, and set operations (union, difference, intersection, and overlay) operations on geographical features.

Other TerraAmazon tools include visualization and database check{}-in and check{}-out procedures.

TerraAmazon Implementation Details

TerraAmazon is a database client application, developed on top of TerraLib geographic components library, using Standard C++ programming language and graphical interface implemented using the free

graphic user interface library QT.[30] TerraAmazon can be executed on LINUX or MS-Windows environments. All data is managed by the PostgreSQL DBMS[31], running on a LINUX server.

Each of the 0.25 degrees cell is blocked by the remote sensing specialist in a long term transaction schema, bounded by check-in and check-out operations. The cell field is used to clip all available geographic representations in order to reduce the amount of geographic elements, guaranteeing manageability of graphic features. For fast visualization these graphic features are cached in memory and indexed by a linear R-Tree (Guttman, 1984). Figure 2 shows a region of Amazon with cell edges highlighted in green.

TerraAmazon topological restriction operations are used during the edition of new deforestation areas and clouds. Before a new deforestation or cloud polygon is stored in the database, TerraAmazon subtracts from the polygon previous deforestation polygons. Figure 3 shows these steps for a new cloud polygon.

(a) Insert polygon over mask
(b) Save polygon in draft layer
(C) After Classification
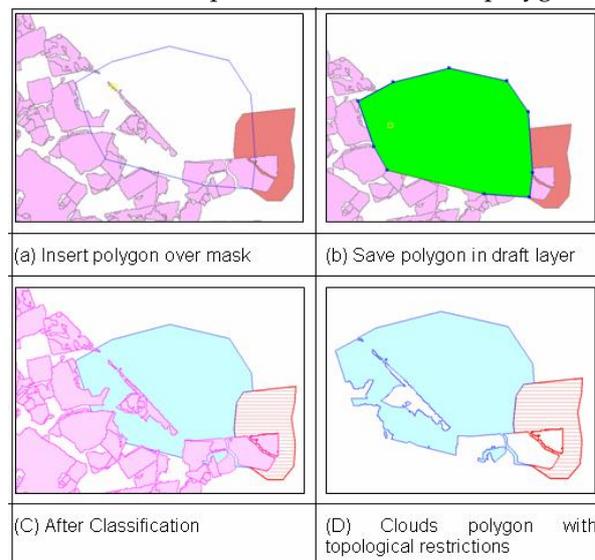(D) Clouds polygon with topological restrictions

Figure 3: TerraAmazon topological restriction applied to a new cloud polygon. The polygon stored in the database is the one presented in (D).

The complete set of TerraAmazon tools is composed by:

1. Import of TIFF image;
2. Georeference using polynomial model calculated from control points;

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[30]QT Library: http://trolltech.com
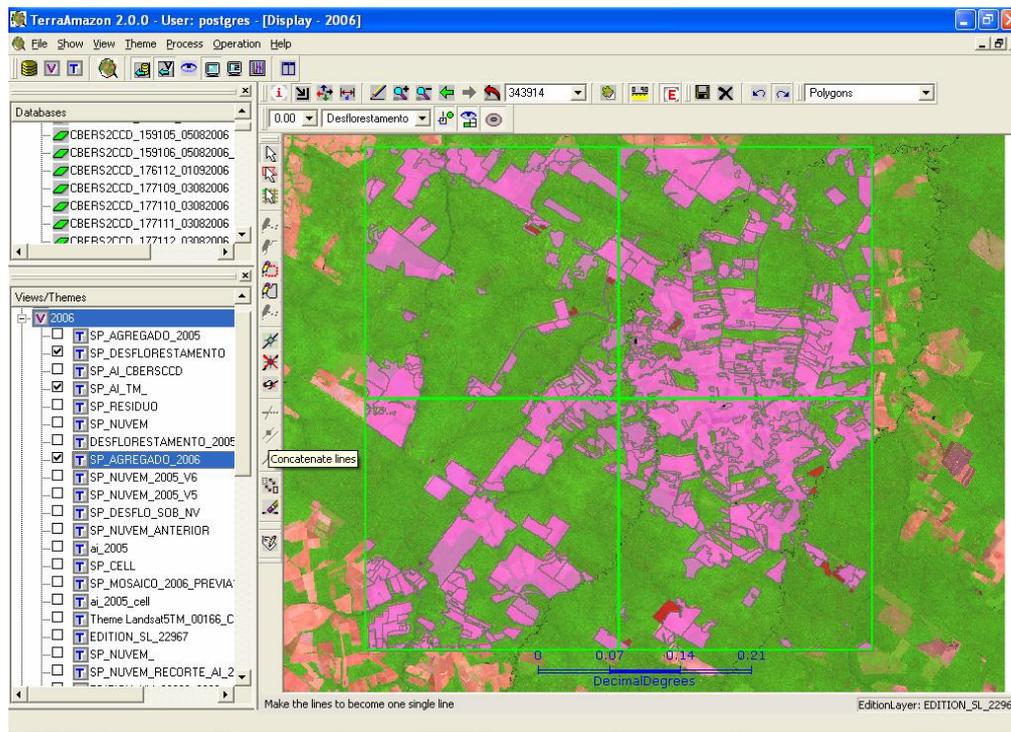[31]PostgreSQL DBMS: http//:www.postgresql.org

Figure 2: Cells (highlighted in green) selected for edition in a small part of Amazon.

3. Image enhancement and color composition;

4. Mixing model analysis; (Shimabukuro,1987); (Shimabukuro;Smith,1991)

5. Image segmentation using region growing algorithm; (Bins et al., 1996)

6. Labeling of regions;

7. Clustering classification;

8. K-means classification;

9. Raster to vector and vector to raster conversion;

10. Graphic interface for vector edition with snap and topological control;

11. Union, difference, intersection, and overlay set operations on graphical features;

12. Check-in and check-out procedures using cells index.

An Internet distribution site is provided, based on a PHP application running on a LINUX Web Server, powered by Apache. The Web application was created on top of TerraLib library, using the TerraPHP extension.

The Internet site feature includes:

1. Seamless visualization of full resolution data;

2. Image visualization, using pyramidal resolution;

3. Export of full resolution features, defined by user;

4. Web Map Server - WMS - access to data;

5. User queries, including deforestation by municipalities and inside protected areas;

6. Deforestation ranking by municipality;

7. Deforestation indices by cell grid;

Figure 4 shows the Internet dissemination site[32].

Deforestation Project Figures

The following figures demonstrate the huge task made possible by TerraAmazon:

• To create the deforestation map for the period 2004-2005, 221 CBERS images, 223 LANDSAT images and 18 DMC images was used, for 2005-2006, 70 CBERS images and 211 LANDSAT images

• During the interpretation phase, in 2006, the system was accessed by up to 20 concurrent

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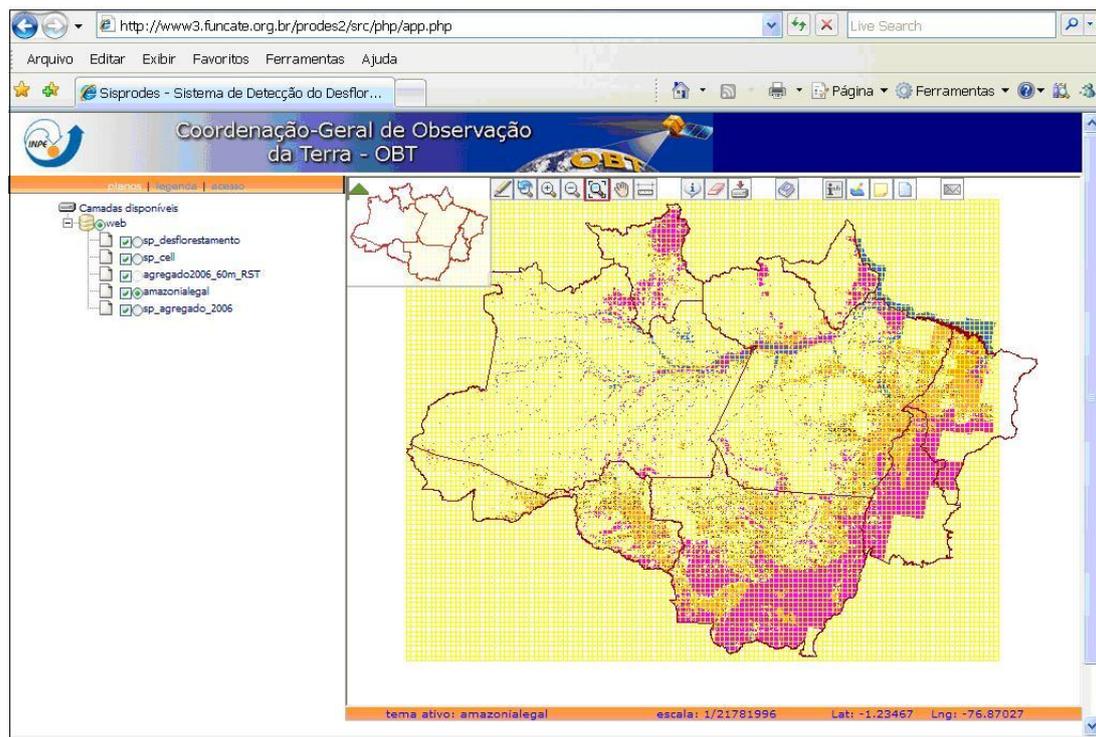[32]Internet dissemination site: http://www3.funcate.org.br/prodes2

Figure 4: TerraAmazon Internet deforestation data dissemination site.

users. These users added 213,693 new deforested polygons and 595,575 new cloud polygons to the database

- The final database stores 2,380,880 polygons, classified in different categories. These polygons are complex - the largest one has 69,925 vertices, the average number of vertices is 59 and the average number of holes per polygon is 7

- The current volume of data stored in database is 237GB and includes full resolution images using a multi-resolution pyramidal RLZ compressed schema

Conclusion

TerraAmazon fulfilled the requirements imposed by the Brazilian Government and has been used since 2005. TerraLib technology is an option to create a complex GIS system, using only open source software and made feasible the implementation of TerraAmazon. In addition, TerraAmazon has been proving to be robust, easy to manage and reliable in a high demand production multi-user environment.

Acknowledgments

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