NEW MAPPING AT SCALES 1:200,000 OF SENEGAL AND 1:5,000 IN FRENCH POLYNESIA: 2 EXAMPLES OF OPERATIONAL PRODUCTION OF DIGITAL TOPOGRAPHIC MAPS FROM SATELLITE IMAGERY

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Abstract
The production of topographic maps from satellite imagery has been limited to pilot areas for a long time. It has only come out in an operational way since the arrival on the market of sensors with high or very high resolution in the beginning of the years 2000.

In this context, SPOT5, launched in 2002, is an unique tool which fits the needs of cartographic production at scales up to 1:50,000, and even 1:25,000 in some countries, thanks to its high resolution (2.5 m or 5 m), its stereoscopic abilities and its wide swath (120 km). We will illustrate its potential with the presentation of PCS200 mapping project of Senegal.

In this country as in most Central or West Africa, 1:200,000 mapping is the bigger scale covering the whole country. Most of the maps have been published, and for some of them revised, between 1955 and 1980. Only a few map sheets have been updated more recently. Obsolescence and precision (both planimetric and altimetric) of these maps do not fit with modern requirements of geographic information quality. PCS200 is the project of complete renewal of 1:200,000 mapping and production of a cartographic vector database of Senegal. This project, contracted to IGN France International, to the benefits of DTGC in Dakar has been financed by European Union. It started in 2004 and ended in July 2008. It is based, for planimetry, on the interpretation of SPOT5 Panchromatic images at 5 m resolution, merged with Landsat 7 Multispectral images with 30 m resolution. The new altimetry (contour lines, spot
heights, relief shading) is derived from a DEM produced from SPOT5 HRS data. DTGC, with the partnership of IGN France, has thus benefited from an efficient, economic and quality cartographic production line. 27 new maps (1°x1°) have been published (in offset and a folded way) and the corresponding vector database is available all over the country (about 200,000 km²). This project was also the opportunity to change the reference projection of the country for UTM/WGS84 zone 28.

On the other hand, satellites with metric or sub-metric resolutions (IKONOS, Quickbird, Worldview-1, Geoeye-1, Kompsat….) allow the production of topographic maps at scale up to 1:5,000. We will present a part of the ‘Topofoncier’ project whose goal was to produce digital topographic maps at scale 1:5,000 on some islands of French Polynesia, from stereo pairs of IKONOS images. In this remote area, the distances between islands or atolls as well as cloud cover make the acquisition of aerial photos very difficult. That’s why, in the framework of the ‘Topofoncier’ project (2003-2008) whose objective was to complete the large scale mapping of this huge territory, IGN France used monoscopic (for atolls which have almost no relief) or stereoscopic coverages (for islands) of IKONOS images (1 m color). On 12 islands or group of islands mainly located in the Marquises archipelago (Tubuai, Rapa, Rurutu, Raivavae, Rimatara, Nuku-Hiva, Mangareva, Ua Huka, Ua Pou, Hiva Oa, Tahuata, Fatu-Hiva) and after geometric modelling in blocks, stereoscopic pairs have been photogrammetrically plotted to produce 114 map sheets at scale 1:5,000, representing about 1150 km² of land area.

These two production works prove that spacetapping has entered a mature phase. As the new sensors that have just or are on the way to be launched (WorldView2, Geoeye-2, Pleiades, SPOT6…) are more and more efficient in terms of resolution, agility, swath and stereoscopic acquisition capacities, we can ensure that the use of satellite imagery for topographic mapping will re-enforce in the coming years.

Introduction

Limitations in terms of resolution and capacity of acquisition have limited the production of topographic maps from satellite imagery to prototypes or small areas for a long time. It has only come out in an operational way since the arrival on the market of enhanced sensors with high or very high resolution in the beginning of the years 2000. In this context, SPOT5, launched in 2002, is an unique tool for the cartographers. It fits the global needs of cartographic production (new production or update) at scales up to 1:50,000, and even 1:25,000 in some countries. This is due to SPOT5 high resolution (2.5 m or 5 m), its stereoscopic abilities and its wide swath (120 km). We will illustrate its potential with the presentation of PCS200 mapping project of Senegal. On the other hand, satellites with metric or sub-metric resolutions (like IKONOS, Quickbird, Worldview-1, Geoeye-1, Kompsat…) allow the production of topographic maps at scale up to 1:5,000. We will detail a part of the ‘Topofoncier’ project whose
goal was to produce, for the local Government of French Polynesia, digital topographic maps at scale 1:5,000 from stereo pairs of IKONOS imagery.

1. New mapping of Senegal at scale 1:200,000 : the PCS200 project
1.1 Context of the Project.
In Senegal as in many Central or West African countries, 1:200,000 is the best scale covering the whole country, as 1:50,000 scale covers only limited areas. These maps have been first published between 1950 and 1960. Some of them have been revised up to 1980 and only a few map sheets have been updated more recently. Moreover, the precision (both planimetric and altimetric) of this cartographic coverage do not fit with modern requirements of geographic information quality. For Senegal, the planimetric errors can easily reach 300 to 400 m and contour lines interval is only 40m. This has leaded the Senegalese Government to decide the update of the geographic infrastructure of the country.

PCS200 is the project of complete renewal of 1:200,000 mapping and production of a cartographic vector database of Senegal, from satellite imagery. This project, contracted to IGN France International, for the benefits of DTGC in Dakar has been financed by European Union (ACP funds). It started in 2004 and ended in July 2008.

1.2. Project objectives
The main objective of the project was, according to the terms of reference, to produce, within 3 years and 3 phases, a digital cartography, up to date and homogeneous, of Senegal by :
• Updating and reprinting the 27 mapsheets at scale 1:200,000
• Producing from the updated maps a digital database called « Sen 200 » in vector form and organized in 5 layers :
  o Administrative and Toponymy
  o Road and Railway networks
  o Hydrology
  o Orography
  o Vegetation (Land use)

1.3. General methodology
The technical process that has been implemented by IGN France consists in :
• Using Reference3D® product available over Senegal as:
  o A source of GCPs, independant from the old maps,
  o The base of the new altimetry
• Acquiring and orthorectifying (without using the old maps) a coverage of satellite images
• Entirely redrawing the new maps in vector form by on-screen interpretation of orthorectified satellite images
• Using as much as possible external data from other Ministries or private companies
• Integrating data from field survey
• Reprinting updated new maps, in offset (Cyan, Magenta, Yellow, black)
• Elaborating the cartographic vector database directly derived from the maps

1.3. Image selection and acquisition
Although the scale of mapping was only 1:200,000, interpretation of tracks and discrimination of urban areas in the context of a Sahelian country like Senegal led us to choose a resolution better than 10m. On the other hand, the need of interpreting the global land use was calling for multispectral imagery. As the budget was restricted, we could not offer the ideal imagery for this project, i.e. SPOT5 in 5m color mode. We opted for a coverage of the whole country (200,000 km²), with 93 SPOT5 scenes in Panchro mode (resolution 5m), mainly selected in the recent archive, plus a Landsat 7 coverage of 12 images acquired in autumn 2002. See figure 1.

1.4. Image geometric and radiometric processing
Landsat and SPOT images have been geometrically modelled together, using the block adjustment software developed in IGN (spacetriangulation module of GeoView software, using orbit parameters and movements of the satellite on its orbit). GCPs have been selected on Reference3D® (DTED2 DEM and orthoimage from SPOT5 HRS data) whose absolute planimetric and altimetric precisions over Senegal are estimated to 10m rms. The old maps have not been used and residuals on GCPs after block adjustment were less than 1 pixel. See figure 2. Both Landsat 7 (bands 2,3,4) and SPOT Panchro images have been orthorectified using Reference3D® DEM (see figure 2). They have been merged (see figure 3), using similar pansharpening process than the one used for merging Multispectral and Panchro images acquired simultaneously by the same sensor. Merged images were further radiometrically equalized and mosaicked per tile of 1°x1°, corresponding to the extend of 1 mapsheet.

Figure 1. Extract of Landsat 7 TM (Bands 2,3,4, resolution 30m) and SPOT 5 Panchro images (resolution 5m) over the city of Tambacounda
Figure 2. Block adjustment of SPOT 5 Panchro and Landsat 7 images and Reference3D® DEM over Senegal

Figure 3. 5m color image resulting of the merging of Landsat 7 TM (Bands 234) and SPOT 5 Panchro image over the city of Tambacounda

Although there is a ratio of 6 between the resolutions of Multispectral and Panchro images and that the 2 coverages have been acquired at different dates (but at the same
season), the resulting Pansharpened images are very close to the original SPOT5 5m color images and they do not lead to misinterpretation.

1.5. Planimetry
Planimetry of the new maps (road, railway and hydrographic networks, land use, urban areas) has been interpreted on the Pansharpened orthoimages, with the help of the old scanned maps in background. We have also used as much as possible external data from other Ministries or private companies (road classification, administrative boundaries, National parks limits, localization of powerlines, health centers, …). Systematic field survey has been undertaken to collect complementary information like road practicability, toponames, administrative limits...

1.6. Altimetry
The new altimetry has been derived from the DTED1 version (pixel-size of 3” of arc, instead of 1” for the DTED2 version) of Reference3D® DEM produced from SPOT5 HRS data. It consists in:
- Shadows from the relief (hill shading image put in background of the maps),
- New contour lines (20m contour interval with supplementary contours at 10m)
- Spot heights

1.7. Results for the country
A new vision of Senegalese territory as:
- 27 new maps at scale 1:200,000 (see figures 4 and 5)
- A digital version of the paper maps in raster form
- A corresponding cartographic vector database
- A new DEM
The main characteristics of this new geographic infrastructure of Senegal are:
- Up-to-Date Information (road network, practicability, urban areas, …)
- New projection UTM on WGS84, zone 28, compatible with GPS
- Folded paper maps for easy manipulation
- Homogeneous legend and presentation over the whole country (see figure 5)
- Planimetric precision compatible with international standards (less than 20m rms in absolute precision)
- New altimetry with an absolute precision of 10m rms
- Digital data (image and vector) available under various formats: Tiff/GeoTiff, DXF, GeoConcept… that can be directly imported into a GIS
- Data of national interest which is the base for various applications and projects

1.8. Full technology transfer
All along this project, DTGC benefited from a full technology transfer from IGN France. It consists in:
- Long term training in France for 5 agents
- Short-term training for 2 agents during 3 months
• Implementation of a complete production line in Dakar (satellite image processing, cartography, GIS)
• On-the-job training, technical assistance for production of the new maps in Senegal, hot line

Figure 4. Extract of old and new topographic map of Kaffrine (ND-28-XV) around Mbaké-Touba

Figure 5. Assembling of the 27 topomaps at scale 1:200 000 over the whole country
2. Topographic mapping at scale 1:5 000 in French Polynesia

2.1. Context of the project
In French Polynesia, the distances between islands or atolls as well as cloud cover make the acquisition of aerial photos very difficult. That’s why, in the framework of the ‘Topofoncier’ project (2003-2008) whose objective was to complete, for the Local Government of French Polynesia, the large scale mapping of this huge territory, IGN France has intensively used satellite imagery. Monoscopic (for atolls which have almost no relief) or stereoscopic coverages (for islands) have been acquired by programming. We will only describe in this paper the production of topographic maps from stereo imagery, on 12 islands or group of islands mainly located in the Marquises archipelago (Tubuai, Rapa, Rurutu, Raivavae, Rimatara, Nuku-Hiva, Mangareva, Ua Huka, Ua Pou, Hiva Oa, Tahuata, Fatu-Hiva).

2.2. Input data
IKONOS imagery has been choosen, mainly thanks to the agility of its sensor in comparison with the only other metric sensor on the market at the beginning of the project : QuickBird. They have been purchased in 1 m color mode, as ‘Geo Ortho Kit’ products, provided with rational polynoms (rpc files). For about half of the surfaces, multitemporal acquisition has been necessary to get at least one cloudfree stereo-image over any point.

2.3. Geometric processing
Stereopairs of IKONOS images have been modelled in blocks (1 block per island), using a block adjustment method for rational polynomials developed in IGN (Geoview software). GCPs were first pre-identified over the raw images and their precise coordinates determined on the ground using GPS techniques.

Figure 6. Localisation of GCPs and tie points over Hiva Oa island.
In the example presented in figures 6 and 7 over Hiva Oa island, 7 stereopairs (2 in multitemporal) have been acquired. 30 tie points have been selected, as well as 13 GCPs for a rms error of 0.3 m in XYZ.

2.3. 3D plotting
After geometric modelling, stereoscopic pairs have been photogrammetrically plotted (using the photogrammetric module of Geoview software) to finally produce 114 map sheets at scale 1 :5,000, representing about 1150 km² of land area. In figure 8, you will find the example of the only topographic map covering the Rimatara island.
Conclusion
These two production works prove that spacemapping has entered a mature phase. As the new sensors that have just been launched or are scheduled in the coming years (WorldView2, Geoeye-2, Pleiades, SPOT6…) are more and more efficient in terms of resolution, agility, swath and stereoscopic acquisition capacities, we can ensure that the use of satellite imagery for topographic mapping will re-enforce in the coming years.

References
Abbreviations

- DEM : Digital Elevation Model
- DTED : Digital Terrain Elevation Data
- DTGC : Direction des Travaux Géographiques et Cartographiques (Direction of Geographic and Cartographic Works, Senegal)
- GCP : Ground Control Point
- GIS : Geographic Information System
- GPS : Global Positioning System
- HRS : High Resolution Stereoscopy (SPOT5 sensor)
- IGN : Institut Géographique National (French Mapping Agency, France)
- PCS200: Projet de Cartographie du Sénégal au 1/200,000 (Mapping Project of Senegal at scale 1:200,000)
- rms : root mean square
- UTM : Universal Transverse Mercator