Evolution in the Use of Space Imagery – Trends and Challenges

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SUMMARY

A retrospective about the evolutions of the Earth Observation from remote sensing to large scale surveys is presented, mostly through the SPOT series of satellites. The new trends offered by small pixel satellites and by automatic interpretation tools are pointed out.

RÉSUMÉ

Un panorama historique rapide est présenté pour permettre de comprendre les évolutions de l'observation de la Terre, partant de la télédétection et se rapprochant désormais des levers à grandes échelles, avec comme exemples la gamme de satellites SPOT. Les tendances actuelles de ce vaste domaine d'activités sont ensuite esquissées, ainsi que les apports de l'exploitation automatique de ces images numériques.

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1. INTRODUCTION

Until the late 80's, surveyors hardly care about the so-called Remote Sensing, and Earth Observation ("EO") users most of the time merely ignored geometry, and all the corpus of photogrammetric sciences, in their daily practice.

On one hand, Landsat 80 m pixel size images were obviously of no use for the surveyor community. On the other hand, Earth Observers, at that time mostly researchers focused on algorithms and methods, could simply not master Landsat complex geometry, if they only considered it. However, as satellite data became of some interest for "real life" applications (geology, forest and crop monitoring, desertification, …), EO users started to be concerned with geometry, and began to complain, because they were not able to co-register satellite data, neither with cadastre, nor with large scale maps, or with any field measurements….

2. FROM SPOT 1 TO SPOT 4

The SPOT satellites were designed to address this deep need of geometry, and photogrammetric techniques actually irrupted into Earth Observation as soon as SPOT 1 brought stereoscopy, in 1986.

- A new field of applications, a new market opened : with their 10 m panchromatic 60-by-60-km images and their stereoscopic ability, SPOT 1, SPOT 2 (launched 1990), SPOT 3 (1993, lost in 96) and SPOT 4 (launched 1998) gave way to DEM (Digital Elevation Model) extraction and small- and middle-scale mapping. It was a big success, mainly used for developing countries, where no geographic information was available yet.

- For the first time EO users could partly get rid of their geometry headache, by ordering SPOT level 2 and 3 products, in their own customised map projection. Control points were still needed to overcome the 400 m absolute horizontal accuracy, but in the mean time GPS was made available…

- Anyway, though an important step ahead, SPOT 1 to 4 could obviously not fill the abyss between EO and field surveys. This is the reason why the surveyor community only slightly grumbled when a South-American province selected SPOT images as a geometric reference for its rural cadastre.

3. SPOT 5 AND NATURAL HAZARDS: THE CASE OF FLOODS

Relatively to the previous SPOTs, SPOT 5 greatly improves image resolution by collecting 2.5 m Panchromatic images over the same 2 x 60 km swath. This turned on-going experimental projects into new operational applications (and markets) such as precision farming, natural hazards prevention, monitoring and damage assessment.

Regarding flooding, EO data now addresses three major needs (most information in this section are extracted from [GOUTORBE, 2002]):

- building of a common database, to be used by all the operational players before, during, and after the flood crisis,
- serving as input into hydrologic models of watersheds basins,
- mapping the flood extension.

3.1 Common Database

This database includes base maps and recent updates, complete information about flood history, land use,…. Any data regarding a better knowledge of the area can be added : geological and pedological maps, land use evolution, … Here SPOT 5 sharp 2.5m imagery provides the possibility to detect newly built features such as buildings, roads,… a very specific key info (known as "vulnerability map") which can greatly influence the flood extension and damages .

3.2 Models

Earth Observation can now provide enough information to describe the water basins and hydrological networks, and build a fairly complete model of the flooding. The physical characteristics of the watershed basins are derived from relief and land use. EO data provides:

- geometry : superficies, orientation, shape parameters, elevation, texture.
- a full description of the water network : local slopes, topographic index, flowing time between 2 points,…
- land cover information (forests, agriculture, bare soils, several classes of urban areas,…) along with their run-off index.

Specialists usually quote other data to fully complete the model:

- a detailed description of the ground features in urban zones. This type of information has been successfully extracted from 1 m resolution Ikonos imagery, but the resulting layer suffers from an incomplete coverage due to visual masks created by the buildings.
- a 1cm-class DEM, to efficiently predict the exact flood extension and damages from the rainfall distribution. Obviously, this type of data can only come from field or large scale photogrammetric survey operations, since Earth Observation systems will not soon be able to provide such a detailed description: time for complementarity.

3.3 Mapping the Flood Extension

Mapping the flood extension is another crucial need, to meet several goals :
- during the crisis, to organise the rescue operations
- for the prevention of the next floods, to give a better knowledge of the past events and to help defining an adequate policy to reduce the risks
- to calibrate hydrological models against real floods

3.4 A Dedicated Service for Emergencies

Space agencies and EO distributors have recently set up a 365 days a year operational alert system, to be able to collect and deliver data of any zone all over the world in emergency cases within a short period of time, less than one day (the final need for rescue planners being estimated between 12 and 24 hours, which implies image delivery within 3 hours). In our opinion, this service foreshadows a more global move of our information business towards the reactive applications allowed by the new generation of EO data.

4. SPOT 5 GEOMETRIC CHARACTERISTICS

Launched in May 2002, SPOT 5 was designed to improve the geometric performances of the previous SPOT models:

- A star tracker was added, which refines the horizontal absolute accuracy,

- SPOT 5 hosts the HRS (High Resolution Stereoscopic) instrument. HRS has 2 telescopes: one pointing forward and one aft of the satellite (see figure 1 below). The forward-looking sensor acquires images of the ground at a viewing angle of 20° ahead of the vertical. One and half minute later, the aft-looking sensor images the same strip at an angle of 20° behind the vertical. The instrument is thus able to cover an area of 600 km x 120 km in a single pass, at a 5m x 10m stereoscopic resolution.

As demonstrated during the in-flight assessment phase and through the continuous monitoring of SPOT 5 geometry, the star tracker, working together with the DORIS positioning instrument, allows for HRS a 15 metres horizontal absolute location accuracy. For all EO users, this is another revolution, because a 15 m absolute accuracy is what most of the users get, when they may benefit from existing 1: 25 000 or 1: 50 000 maps.

5. SPOT 5 STEREO SENSOR BUILDS A HUGE 3D DATABASE: REFERENCE3D

HRS stereopairs are acquired systematically over wide areas. Spot Image and IGN are currently exploiting them to gradually build up a huge database named Reference3D. Routine yearly production pace is expected to survey up to 6 million sq.km after the first year.

- Reference3D is a global database which includes three layers, all with 15 m absolute location accuracy:
  - a DEM: 1 arc second posting (30 m on the Equator, 20 m in Paris)
  - an orthoimage: 1/6 arc second posting
  - a full set of quality and source files

- Reference3D can be used within an automated process to orthorectify any EO optical imagery: the orthoimage acts as a precise map, to which any incoming EO optical image can be linked through tie points, the DEM being used afterward to correct the relief. This way, SPOT 5 is able to acquire in a single pass the necessary set of data to automatically produce 2.5 m orthoimages with a 15 m absolute accuracy.

- So, for the EO user, as long as this 15 m accuracy is acceptable, ground control points (GCPs) are not needed any longer! Reference3D must then be considered as the definitive remedy against geometric headache.

- Regarding survey operations, the automated production of 2.5m orthoimages will certainly prove interesting and efficient, either for some rural cadastre, or timber plantations, open-sky mining or even 1:5,000 quick-mapping of growing suburbs, once (manually) relocated to a 2 m accuracy with adequate GCPs and rectified upon the Reference3D DEM. A ditch does remain, but it is narrowing.

6. FUTURE TRENDS, FUTURE CHALLENGES

The Pleiades satellites will continue SPOT’s mission. These satellites are currently under design at CNES (French Space Agency). Their 70 cm resolution images will open new application domains, reinforce the penetration of EO data into the “real life”, as can be seen from Ikonos and Quick Bird.

To achieve this, we will have to implement important changes in (at least) two directions : towards reactivity, and towards automatic extraction of information. The «emergency service» and Reference3D prefigure these two directions.

6.1 Reactivity

Reactivity shall apply to both satellite and ground systems :

- EO satellite are not so numerous, and their individual revisit capability is currently limited to once a day, in best cases (3.5 days for Ikonos). We will need an adequate number of agile satellites.

- In emergency cases (not only hazard emergencies, but also commercial, political, security…), the use of EO data is hindered by the processing and delivery time. We need to develop reliable 7/7 services, mostly automatic, with the lesser impact upon the existing staff, to minimize the cost.

6.2 Automatic extraction of information

"Users want relevant information, not images" has become a motto. Nevertheless, the processing of EO data usually requires experts or heavy interactive steps. In the emergency flood service above described, the extension of the flood is being drawn visually from the image, because no automatic procedure exists to do so, and this causes a several hour delay in the delivery to the final users!

To develop the use of EO data, we need reliable automatic tools to detect and/or extract information relevant to many users: clouds, water, seashore, roads and railways, airports, industrial plants….. No research program has been settled yet. For the moment, scientific works show mitigated results, that could inspire a pessimistic approach: since it seems difficult, let us rely upon the current heavy and costly and time-consuming interactive steps (which discourage the users).

However, one must consider that nearly all these results were achieved considering the sole image. Hopefully, a very promising area of research is now open by the existence of global vector databases (eg. VMAP 1) that could back cooperative methods: the problem is not any more to find unknown objects from the image itself, but to retrieve objects which are described (including geometry) in the existing database. These methods show very encouraging results (Dhérété – 1999) (Villecrose – 2002)

7. CONCLUSION

I agree: all this will not be easy. But let me tell you a story.

A few years ago, Spot Image was called by the CNES to participate in the early design of the Pleiades system, to tell the users' needs. Of course, we had geometry in mind! And we focused upon three key points:

1. Absolute location accuracy without GCP : 10 m or better, to cope with GPS standard
2. Single pass 3-images stereoscopy (aft, vertical, rear) to increase DEM quality and completeness over building areas and sharp slopes. With a constellation of at least 2 satellites (6 images), one can expect to avoid masks and collect stereoscopic data over the whole area.
3. Perfect registration of the spectral channels onto the Panchromatic one to get colour images without any blurring or iridescence on buildings and cliffs

At first, these characteristics were felt "unrealistic", "impossible" for a 500 kg satellite, and their real necessity questioned, … as well as the mental health of the speaker. But time passed, teasing did not cease, and people slowly get convinced: new technologies were experimented, and Pleiades has now fulfilled two (and half) of the above requirements.

The quest is still going on!

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Fig 1 : HRS acquisition process
Each pixel line is acquired twice, after 90 seconds
120 km strip width ; maximum length : 600 km