SPOT A NEW CARTOGRAPHIC TOOL

Guy Rochon, Th. Toutin
Digim (1983) Inc. - Montreal, Canada

SUMMARY

DIGIM is currently developing, within a contract from the Canadian Department of Energy, Mines and Resources, an entire system for base mapping using SPOT stereoscopic images and a few GPS points as input.

First, the authors describe the software and hardware components of the system. On the basis of performance results obtained so far, the production costs of base mapping with SPOT and GPS are evaluated and compared to the costs of conventional methods. The ratio of these two costs for maps at a scale of 1:50,000 is in the order of 1:2.

When operational, the system being developed will therefore offer a great advantage over conventional methods for digital mapping at medium and small scales, not only because of the reduction in production costs and delays but also because many new digital remote sensing products such as DTMs, spatio-maps, etc., can be offered to users.
1. **INTRODUCTION**

Approximately 60% of the earth's total land surface, or some 50 000 000 square kilometres, remains to be mapped at scales ranging from 1:40 000 to 1:125 000.

In addition, 20% of the earth's land surface has not yet been mapped at a scale greater than 1:140 000.

Furthermore, there is an increased need for digital base maps as an input in geocoded land information systems. Thus, it is evident that there is a great need for cartographic products in the world and much revision of existing maps remains to be carried out.

To meet this need as much as possible, the Canadian Department of Energy, Mines and Resources through the Surveys and Mapping Branch and the Canada Centre for Remote Sensing awarded a contract to Digim in 1985, for the development of highly automated methods and software for use with high-resolution SPOT satellite imagery to obtain DEMs (digital elevation models) and topographic maps and basic data for map revision at scales of 1:50 000 and smaller.

In this paper, the whole system which uses SPOT images and which should become operational in a few months, is described as well as its performance and the products deriving from it.
2. METHODOLOGY

The logical structure of the system is shown at figure 1.

First, stereoscopic panchromatic and multispectral images are acquired by the SPOT satellite, transmitted to the receiving station and sent to Digim. After having received the images, they are visualised and some well identifiable GCPs (ground control points) are chosen within the block: road crossings, field boundaries, etc. Then the which allows to compute the X, Y, Z coordinates of all the GCPs.

Subsequently, the image coordinates of the GCPs are measured using the image display and entered into the system along with known terrain coordinates. The spatio-triangulation process then determines the terrain coordinates of many points whose image coordinates were given to the system. These new GCPs may be used for the geometric correction of the already acquired images or of any subsequently acquired images in which those points clearly appear.

The automated image correction and stereocompilation process comprises many steps that will be described at the section on data processing. The products that can be directly generated by this process are DEMs (digital elevation models), DTMs (digital terrain models) and ortho-images. While DEMs are automatically generated by the system and some of the feature extraction is performed through image classification, most of planimetric information is extracted through interactive image interpretation. Finally, all cartographic data are edited on graphic stations before the different overlays of the digital map are produced. By combining geometrically corrected SPOT images with digital maps, spatio-maps are obtained.
FIGURE 1

Methodology

SPOT

Image acquisition

GCP's survey

Data pre-processing

Spatio-triangulation

Automated image correction and stereocompilation

Image interpretation

Map edition

Spatio-triangulation points

DEM, DTM, spatio-maps

Digital maps

Editing

Planimetric details

Vegetation

Hydrography
3. COMPONENTS OF THE SYSTEM

3.1 Data acquisition and pre-processing

Data acquisition and pre-processing are performed outside the system. Image data acquisition is done through the SPOT Image distribution network. In this respect, DIGIM is the official distributor in Canada for SPOT data and a worldwide distributor of SPOT-derived products and services.

Pre-processing of raw SPOT data to obtain level 1 images is performed at the various receiving stations.

3.2 Data processing

Figure 2 shows the main processing steps for the software component of the system.

Spatio-triangulation

By analogy with aerotriangulation, spatio-triangulation is the process of extending horizontal and vertical control by relating the measurements of angles and distances on overlapping images into a spatial solution using the perspective principles of SPOT imagery and the particular geometry of the satellite orbit.

The spatio-triangulation process uses, as input, GCPs image coordinates, data relative to the attitude of the satellite, which are measured on board, and a few GCP terrain coordinates and determines the terrain coordinates of new GCPs.
FIGURE 2
Main Processing Steps of Data Processing

- Stereoscopic SPOT image
  - Spatio-triangulation
    - Geometric correction
      - Automatic generation of DEM
        - Resampling
          - Raw DEM
            - Correction of DEM
              - Corrected DEM
                - Raster vector conversion
                  - Editing
                    - Planimetric details
                    - Vegetation
                    - Hydrography
                    - Orography
                    - New GCPs set
Automatic generation of DEMs

One of the stereoscopic images is taken as the reference image and the other as the candidate image. A digital matching algorithm is used to determine the $x$ and $y$ parallaxes of the candidate image relative to the reference image. With a geometric model, the $x$ and $y$ parallax files are used in spatial intersection software to generate a DEM that is a kind of image file in which values correspond to the elevation. The DEM is filtered to remove false elevation values and interpolated in order to obtain an elevation value for each regular grid cell.

Resampling

On the basis of the correspondence between terrain and image coordinates, the fractional image coordinates corresponding to each X, Y, Z DEM point are determined and one of the stereoscopic level 1 images is resampled to obtain an ortho-image, that is, an image in which relief-induced distortions are also corrected and which is superimposable on a map.

In the case of high relief variations causing too many local distortions within matching windows during the image matching process, the resampling and the automatic generation of DEMs can be executed iteratively. Level 1 images are then resampled with coarse resolution prior to image matching and the raw temporary DEM obtained is used to resample the input image again to reduce relief-induced distortions. This process is repeated from coarse to fine resolution until the final ortho-image is obtained.
Feature identification

Feature identification is the process of using image classification, edge detection and visual interpretation in order to extract from the ortho-image all the surfaces that correspond to vegetation, lakes, water bodies, roads, etc.

Stereo ortho-images are generated with the DEM to enhance the visual perception of the photointerpreter. Photointerpretation is done directly on the screen with a graphic pad and a special device which shows the relief via color stereo images.

Correction of DEMs

Masks are generated over vegetated areas and water bodies. These masks are then used to impose constraints on the elevation values of the DEM. Local offsets are applied to correct for the vegetation effect, all values over a lake are set equal, etc.

Raster-vector conversion

In the case of altimetry, raster-vector conversion entails following the path of each contour level within the DEM and creating a vector file compatible with the graphic system. For the other groups of cartographic data, this operation first consists of a boundary extraction for each thematic surface generated during the feature identification. Closed and open polygons are then also transformed into vector format.

Raster-vector conversion also includes the validation of the different polygons on the graphic system.
First, the vector files are transformed into graphic files and the cartographic elements are visualized on a graphic station. The appropriate symbol is attached to each type of element, sight and coding corrections are made, and place names and final touches are added to the digital map.

The equipment supporting the system being developed is shown in figure 3. It is composed of an image analysis system with an array processor for spatiotriangulation, image correction, stereocompilation, etc., an interactive graphics processing system, for cartographic data edition and drawing, micro-computers with color monitors and graphic facilities for image interpretation, and many input and output devices.

4. PERFORMANCE OF THE SYSTEM

In order to evaluate the ability of SPOT products to compete with cartographic products derived from photographic surveys, the following scheme was imagined:

1) the entire area to be mapped represents about 150 map sheets of 770 km\(^2\) each;

2) the sample area presents very high relief variations and few planimetric details;

3) the comparison is made between digital mapping with a stereocompiler linked to a digital cartographic system and mapping with SPOT and GPS data.
FIGURE 3

HARDWARE COMPONENTS OF THE SYSTEM FOR DATA PROCESSING
The following figures are presented as a rough comparison of both methodologies and should not be taken as firm prices of Digim’s services and products. For conventional methods, they represent the average costs of mapping in the conditions mentioned above. The figures for mapping with SPOT and GPS are based on an analysis of the time performance of the system to achieve the different processing steps.

Table 1 gives operator and system time for mapping 1000 km² at a scale of 1:50 000 and for each major processing step. Table 2 compares the costs of mapping with SPOT to the costs with conventional methods.

As can be seen in table 2, the decrease in cost by mapping at a scale of 1:50 000 with SPOT should be in the order of 50%. Finally, table 3 compares the costs of some typical products obtained with both methods.

5. CONCLUSION

The system being developed for digital mapping at a scale of 1:50000 or smaller, from SPOT data offers great advantages over conventional methods:

1) Reduction of production costs in the order of 50% for base maps and 75% for ortho-images and DEMs

2) Reduction in production delays

3) Possibility of integration of the digital products with remote sensing images from other sources and geographic information systems.
These major advantages should in the future offer many countries the opportunity to acquire digital mapping bases which they could not have afforded otherwise. Thus, these countries will be able to construct geographic information systems by which to improve their resource management techniques.

### TABLE 1

**Time required for mapping 1000 km² at a scale of 1:50 000 with SPOT**

<table>
<thead>
<tr>
<th>Step</th>
<th>System time (h)</th>
<th>Operator time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatiotriangulation</td>
<td>1,5</td>
<td>2,5</td>
</tr>
<tr>
<td>Geometric correction</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>Automatic generation of DEMs</td>
<td>4,0</td>
<td>2,0</td>
</tr>
<tr>
<td>Resampling for ortho-image(1)</td>
<td>0,5</td>
<td>0,5</td>
</tr>
<tr>
<td>Feature identification</td>
<td>100,0</td>
<td>100,0</td>
</tr>
<tr>
<td>Correction of DEMs</td>
<td>0,5</td>
<td>0,5</td>
</tr>
<tr>
<td>Raster-vector conversion</td>
<td>4,0</td>
<td>1,0</td>
</tr>
<tr>
<td>Edition</td>
<td>120,0</td>
<td>120,0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>231,5</strong></td>
<td><strong>227,5</strong></td>
</tr>
</tbody>
</table>

(1) In this example, the DEM and the ortho-image are generated with only one iteration.
### TABLE 2
Comparison of the estimated costs per square kilometre with both methods (in CDN$).

<table>
<thead>
<tr>
<th>Step</th>
<th>Cost with conventional methods</th>
<th>Cost with SPOT</th>
<th>Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic survey</td>
<td>12</td>
<td>1</td>
<td>Only 10 XYZ points are required for the entire block of 150 map sheets.</td>
</tr>
<tr>
<td>signalization</td>
<td></td>
<td></td>
<td>55 stereo panchromatic scenes + multispectral scenes, OCT + film, for the</td>
</tr>
<tr>
<td>Acquisition of</td>
<td>25</td>
<td>4</td>
<td>entire area.</td>
</tr>
<tr>
<td>images</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatio/Aerotriangulation</td>
<td>1</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Stereocompilation</td>
<td>17</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Edition</td>
<td>9</td>
<td>7</td>
<td>The costs for these operations are assumed to be the same with both methods.</td>
</tr>
<tr>
<td>Drawing</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Color separation</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Field checking</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>85</strong></td>
<td><strong>40</strong></td>
<td></td>
</tr>
</tbody>
</table>
## Table 3

Comparison of the costs per square kilometres for some typical products obtained with both methods.

<table>
<thead>
<tr>
<th>Products</th>
<th>Costs of products per km²</th>
<th>SPOT mapping</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital mapping with aerial photos</td>
<td>85$</td>
<td>42$</td>
<td>50%</td>
</tr>
<tr>
<td>Ortho-image orthophoto</td>
<td>50$</td>
<td>13$</td>
<td>74%</td>
</tr>
<tr>
<td>DEM</td>
<td>48$</td>
<td>12$</td>
<td>75%</td>
</tr>
</tbody>
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