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The IGN digital camera system in progress

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ABSTRACT

The latest progress of IGN's project on digital cameras, that has begun in 1991, are described. The features of the present prototypes are presented. The results of the first attempt to use digital images in IGN production lines are given, either in color with an orthophoto on the city of Rennes, and in panchromatic with a survey over the city of Saumur for the production of IGN's BDTOPO®. The trends of the project are then briefly assessed.

1. INTRODUCTION

The superior quality of directly digital images is now firmly established (Thom, 97), and the questions are now first to obtain from the industry a viable acquisition system, and second to integrate this new kind of data into the existing geographic information production processes.
The IGN's digital camera project, already described in (Thom, 97), resulted in the production of some prototypes of digital aerial camera, either color or black and white, and made it possible for us to focus on the second point as soon as the previous year (1998), leaving the first for the industrials to solve.

2. THE CAMERAS' FEATURES

Let us briefly review the features of the prototypes we used for our work :

<table>
<tr><th>Features</th><th>Color Camera</th><th>B&W Camera</th></tr>
<tr><td>Sensor manufacturer</td><td colspan="2">Kodak</td></tr>
<tr><td>Pixel size</td><td colspan="2">9 microns</td></tr>
<tr><td>Sensor size</td><td>3072x2048</td><td>4096x4096</td></tr>
<tr><td>Antiblooming protection</td><td>yes</td><td>no</td></tr>
<tr><td>Digitization</td><td>8 MHz, 12 bits</td><td>8 MHz, 12 bits</td></tr>
<tr><td>Signal/Noise</td><td>300</td><td>300</td></tr>
<tr><td>Dynamic range</td><td>2000</td><td>3000</td></tr>
<tr><td>Minimum period between shots</td><td>1.4 s</td><td>3.8 s</td></tr>
<tr><td>Minimum ground pixel size
(in stereo, 60 % overlap,
Plane speed=80m/s)</td><td>15 cm</td><td>20 cm</td></tr>
<tr><td>Storage type & capacity</td><td colspan="2">2 Hard Disks, 10MBytes/s,
20 GB, extensible (hot removable)</td></tr>
<tr><td>Forward motion compensation</td><td>Electronic, up to 22mm/s,
accuracy : 1 pixel</td><td>Electronic, up to 22mm/s,
accuracy : 1/2 pixel</td></tr>
<tr><td>GPS interface for date and position of shots, integrated in header of images</td><td colspan="2">Yes</td></tr>
<tr><td>Lenses</td><td colspan="2">- 30 mm, 1/500s min. (Schneider Distagon)
- 40 mm, 1/500s min. (Schneider Distagon)
- 50 mm, 1/1000s min. (Schneider Super-Angulon PQS)
- 80 mm, 1/1000s min. (Schneider Planar)</td></tr>
<tr><td>Number of available prototypes</td><td>2</td><td>2</td></tr>
<tr><td>Real time display of images</td><td colspan="2">Yes</td></tr>
</table>

Table 1: Characteristics of the Cameras.

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The color is obtained in the color CCD by putting small filters of different primary color in front of each pixel, following a special pattern. A pixel then sees only one color, the others having to be interpolated from their neighbours. Since the color filters are far from perfect, and the sensitivity of the sensor different in each spectral band, some colorimetric processing and sensor calibration are also needed to obtain a good resulting color. A good amount of work has been invested in this field to achieve satisfactory results.

R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B

Figure 2: Colored pixel pattern.

Many points of minor importance have also been lastly improved, in the electronics to ease the production of the camera, and improve the dynamics, and in the software, particularly in the user interface to make the system operable by IGN's planes usual staff.

Figure 1: The camera system.

3. THE SURVEYS REALISED

Since the survey over Le Mans in black an white and in color that we described during the PHOWO 97, two main surveys have been flown : one in panchromatic over the city of Saumur, for the production of the BDTOPO®, and one in color over the city of Rennes, to produce an orthophoto.

3.1 The SAUMUR survey

It has been realized in June 98. An area of 30x20 km has been surveyed, in 9 axis, at a ground pixel size of 67 cm. The camera used was the panchromatic 4k x 4k. The along track overlap was 70 %, the across track overlap 20 %. The flight altitude was 3800 m and traditional photographs have been taken every other axis, for comparison purpose, and in security. At that time, only a 50 mm lens was available, leading to a very poor base over height ratio of 0.2. A B/H ratio of 0.4 was nevertheless achievable thanks to the 70 % overlap, skipping one image to form the stereo pairs. Unfortunately this feature was not used during the plotting of the survey.
The work on this survey is not yet fully completed. It has been for the moment used to :

- test the automatic tie points measurement of some commercial software, with mixed results
- plot a stereo pair. Several problems have been detected :
    - ♦ particularly for the display of the image, the linear dynamics of the raw image being too contrasted for a CRT display
    - ♦ a resampling of the image at an equivalent of 50 cm ground pixel size have been done to get nearer the usual value of 40 cm
    - ♦ the poor B/H ratio has led to a bad altitude determination

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- ♦ the blooming of some areas made it impossible to plot some objects and even in some cases relatively large area
- test an automatic DTM measurement software, with good results even in very uniform areas

To conclude, it seems that some developments are still needed to make the use of this kind of images in the present production line easier, especially with commercial softwares.

3.2 The RENNES survey

It has been realized in September 98. An area of 11x10 km has been surveyed, in 15 axis, at a ground pixel size of 30 cm. The camera used was the 3k x 2k color. The along track overlap was 70 %, the across track overlap 20 %. The flight altitude was 1700 m and traditional photographs have also been taken every other axis. The 50 mm lens was also used. It is the highest resolution survey realized at this time at IGN with a digital camera. It is also the biggest in term of number of images: 1068 shots were taken...
The digital images were used to produce a orthophoto of the urban area, the traditional to produce a DEM to be used to construct a 3D city model, with the color images mapped on it.
To overcome the problems arising from the high number of images, many new techniques, still at the research level at IGN, have been used:

- automatic production of a photoindex with computation of approximate image position, to initiate the :
- automatic tie points determination (a total of 4144 points)
- use of the new aerotriangulation program TopAero-PC, with only 70 ground control points taken on a previous traditional survey at the 1/30 000 scale.
- rectification and mosaicking with the process used for spatial images, at the IGN-Espace department, in Toulouse.
  This work has been very interesting, because it has proved that the use of (relatively) small images was a surmountable problem, given the adequate automatic tools. It has also brought a lot of information:
- The human part in the whole process is relatively small, and will be even smaller in the future, limited in fact to the pointing of the ground control points, and to a small number of digital data manipulation.
- The process of tie points determination (produced by the MATIS Laboratory a t IGN) is very successful. The quality is excellent, with an rejection ratio during aerotriangulation of only 0.65 %, and residuals of 0.2 pixel RMS.
- The number of ground control points is not proportional to the number of images. For a traditional survey of this size, a total number of 2 000 control points would have been used. Actually, only **70** have been used...
- The excellent quality of automatic measurements shows also that no significant geometrical systematism is present in the image. It confirms that CCD arrays are geometrically very stable and very accurate, and that no on the pixel basis geometrical calibration is necessary. For this work, the camera system (CCD+lens) was calibrated using only a radial model.
- The mosaicking process showed that the radiometric quality was such as no adaptation was necessary between adjacent images along track. Between tracks, a slight difference is sometime visible, depending on the nature (in fact the 3D texture) of the ground. These are bi-directional reflectance effects, and are not caused by the camera.

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- The most surprising difficulty was to find the good parameters (gamma correction,...) to adapt the linear response of the camera to the eye of the customer, which is used to photographs.
- The fact that the sensor is a mosaic of colored pixels leads to small colored artifacts, when contrasted linear details are sub-parallel to the axis of the sensor. With this ground pixel size, this problem seems not very important for a visual use of the image. For more sophisticated uses, like DEM or building extraction, or different scales, it might reveal a problem.

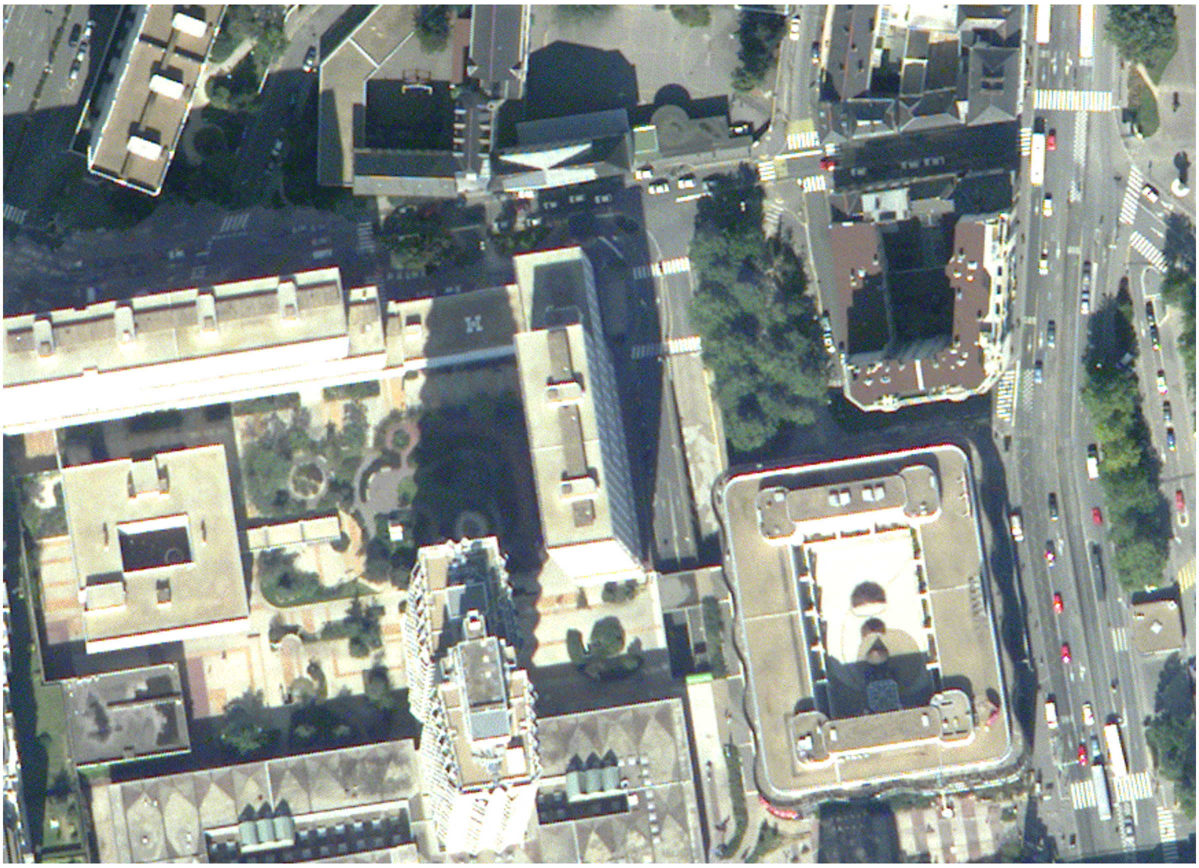

Figure 3: Orthophoto over Rennes. Data come from 4 different images.

4. CAMERA DEVELOPMENT PERSPECTIVES

Two axis of development are considered :

First, it is planned to assemble and synchronize from two to four cameras. This work will lead to the construction of two new camera systems :

- a true color camera, with three colored and maybe one NIR channels. With this camera system, real color images, without the artifacts caused by the color mosaicking, will be produced. With the NIR channel, the remote sensing applications will be accessible, with a highest geometrical resolution than with the spatial imagery, and with a good radiometric quality, unattainable with aerial photography
- a wide field panchromatic camera, by tilting the axis of the cameras in different directions. This will reduce the flight costs by increasing the system swath.

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Second, it is considered to order from KODAK a new class of sensor, a 4k x 4k with antiblooming capacity and blue enhancement, and maybe even a 4k x 4k color sensor based on the same technology as the 3k x 2k. The present sensors are relatively insensitive in the blue spectral range. It causes a poor response in the shadowed areas for the panchromatic sensor, and a bad signal to noise ratio in the blue channel for the color sensor. With this new technology, these problems will be solved, together with those caused by the blooming. The increase in size for the color sensor will lead to a better swath and then to an improvement of the flight cost.

5. SURVEYS PLANNED FOR 99

The production of a digital orthophoto in color over the whole Ile de France region (about 150x100 km²) with a ground pixel size of 1 m, plus the urban parts of this area with a ground pixel size of 50 cm has been decided this year. The flights have started the 26th of May. It will amount at about 20 000 images of 18 Mbytes and represents then about 360 Gbytes of data (+240 Gbytes for raw data).
A survey with the future multichannel camera is scheduled for the autumn 99 / spring 00 over the Bassin d'Arcachon, near Bordeaux, for a remote sensing application.
An area around the city of Amiens has been equipped with landmarks to provide a test zone for various applications (aerotriangulation, building extraction , etc.). This area will be flown during multiple surveys, at different ground pixel sizes, to constitute an image data base to help customers to choose the ground pixel size for their application, the notion of scale having no meaning anymore in digital imagery.
It will also be flown with the future wide field camera to acquire some images to develop the software that will mosaic the partial images into a big one, and to measure the geometrical stability of the mount in normal flight conditions.

6. CONCLUSION

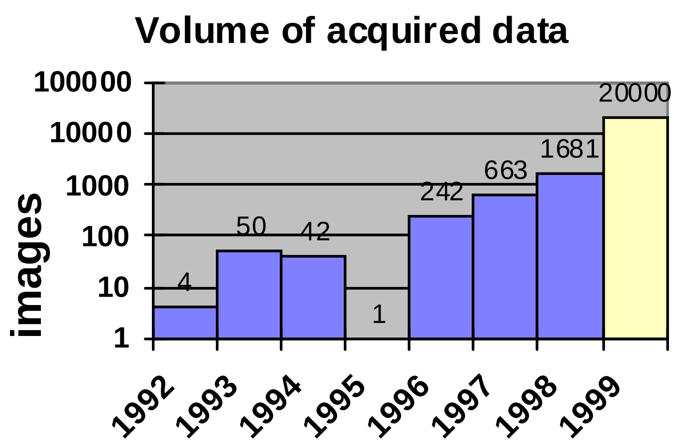

Figure 4

The good quality of the images produced by IGN digital camera, in color and black and white, has convinced customers, inside and outside IGN, to order surveys, despite the over-cost due to the small size of the sensor. New automatic tools have been proved necessary, developed and used to overcome the problem of the number of images. With these new tools, the digital camera seems quite usable for production, and the success achieved on the Rennes survey has led IGN to undertake a very large project of 15 000 km² over the Ile de France, that has started during spring 99.
In parallel to this start in production, the development of new camera systems is undertaken to obtain a wide field and a multichannel color camera that will reduce the flight costs, and yet

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increase the image quality. The radiometric ability of the camera will allow it to aim at remote sensing applications.
As it is shown in the fig. 4, the use of digital camera is really now taking off. The digital cameras leave the status of "research instrumentation" and get into the field of devices used to produce real geographic information.

7. REFERENCES

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