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Current Status of the Digital Camera IGN

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ABSTRACT

The current state of IGN's project on digital cameras, that has begun in 1991, is described. The features of the present prototypes are presented. The results obtained on two surveys in winter and in summer are described and commented. Since these results have convinced IGN's users of the interest of aerial digital data, these cameras will start in 1997 to be used for IGN production purposes.

1. INTRODUCTION

The development of digital stereoplotters and of digital orthophotography leads to an increasing need of digital images. For example, at IGN today, a quarter of the production lines of our topographic data base (BD TOPO®) are digital. This phenomenon will still become more important when automatic or semi-automatic stereo-plotting processes (e.g. DEM or DTM extraction, roads and buildings extraction,...) will exist, and with the advent of more affordable PC based digital stereoplotters. The image acquisition step will soon be the only analogical part of the whole plotting process.

The process of scanning pictures is time consuming, costly, and impairs the quality of images. More, the results are so irregular that sometimes a visual control of all the scanned images of a survey must be done. So the users will look more and more in direction of digital sensors, that, despite their small size with respect of traditional cameras, have a lot of advantages beside producing directly digital images, like sensitivity, a very good image quality, etc.. A comparison between scanned films and digital images can be found in (Thom, 1997)[2].

The soon arrival of spatial digital image at a metric resolution will fulfill some of the needs of these users, but there is a big market for still higher, decimetric, resolution digital images, for example for urban areas, that are unattainable by spatial means for the moment. This market will in fact be boosted up by the existence of these spatial images, since users will get the necessary equipment to work with them.

It appears then that the need of aerial digital cameras will increase in the very next years. In the USA, there are already operators who propose digital surveys and

Figure 1: The camera system.

[2] This study have shown that the Signal/Noise ratio anywhere in the dynamic range of a digital image is much better than in a scanned film. For example, the signal/noise ratio of a digital image is greater than 100 over 90% of the dynamic ; a picture scanned with relatively large pixels of 40 microns shows at its best light level a signal/noise ratio of 30. Let us recall that the signal to noise ratio in a digitized picture is roughly proportionnal to its linear dimension, so if we would like to have the same quality in digitized images we should use a pixel of about 200 microns, that is in fact produce images of 1100 x 1100 pixels, with respect to our 3000 x 2000 pixels.

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digital aerial cameras. The cameras we use now in IGN are designed and built by IGN itself because, at least at the beginning of the project, it was not possible to find on the market a convenient camera for our various applications. There is today an increasing number of equivalent projects in the world, most of them using off-the-shelf cameras (King, 1995), (Mills, 1996), (Bobbe, 1996), ...

2. THE CAMERAS' FEATURES

The very first camera described in (Thom & Jurvillier, 1993) that we used in 92-93 has been abandoned. It characteristics in terms of readout rate (one frame every 20 s) were far to poor to be used in a production context, and the image quality was hardly higher than digitized images. We decided then to realize ourselves a camera more suited to our applications.

Features	1993 Camera	1996 Camera	1997 Camera 1	1997 Camera 2
Sensor size	4096 x 4096	3072 x 2048	3072 x 2048	4096 x 4096
Color	No	Possible	Possible	No
Digitization	1 MHz, 12 bits	5 MHz, 12 bits	8 MHz, 12 bits	8 MHz, 12 bits
Signal/Noise	90	300	300	300
Dynamic range	< 500	3000	2000	2000
Minimum period between shots	20 s	4 s (12 bits), 2 s (8 bits)	2 s (12 and 8 bits)	5 s / 12 bits 3 s / 8 bits
Minimum ground pixel size (in stereo) Plane speed=100m/s	1,20 m	50 cm (12 bits), 25 cm (8 bits)	15 cm	30 cm / 12 bits 15 cm / 8 bits
Storage type & capacity	1 fixed hard disk of 1 GByte	2 Hard disks, 3 MBytes/s, 8 GB, extensible (hot removable)	2 Hard Disks, 10 MBytes/s, 20 GB, extensible (hot removable)	2 Hard Disks, 10 MBytes/s, 20 GB, extensible (hot removable)
Forward motion compensation	No	Electronic, up to 22 mm/s, accuracy : 1/2 pixel	Electronic, up to 22 mm/s, accuracy : 1/2 pixel	Electronic, up to 22 mm/s, accuracy : 1/2 pixel
GPS interface for date and position of shots	Yes	Yes	Yes	Yes
Lenses	24 mm, 1/150 s min. (Optique Thévon)	24 mm, 1/150 s min. (Optique Thévon)	- 24 mm, 1 / 150 s min. (Optique Thévon) - 50mm, 1/1000s min. (Schneider Super-Angulon PQS)	- 24 mm, 1 / 150 s min. (Optique Thévon) - 50mm, 1 / 1000 s min. (Schneider Super-Angulon PQS)

Table 1: Characteristics of the Cameras.

The new cameras (see Figure 1) have been designed and built in our laboratory around the Kodak CCD frame sensor KAF-6300 (3072 x 2048 pixels). The cameras exist in panchromatic or colour version (with a loss of geometric resolution). Their characteristics are listed in the table 1 below. The second camera has been designed in 97 taking into account exploitation and ergonomic problems that occurred with the first one, and the general trend toward smaller ground pixel sizes. Specifically, a faster storage media have been used and a faster readout rate has been implemented, the hard disks sustained data rate being the limiting factor in the first camera. A new interface has also been realized for the electro-optical shutter, so the Schneider Rollei PQ and PQS lens series can be used, in addition to our 24 mm from Optique Thévon.
In 1997, a third camera based on the same electronics will be realized using the Kodak KAF-16800 CCD frame sensor (4096 x 4096 pixels). Its main features will be: a readout frequency of 8 MHz, a minimum period between shots of 5 s in 12 bits that is a minimum ground pixel size for stereo images of 20 cm, and, in 8 bits, a period of 2 s that is a ground pixel size of 12 cm. This camera is more oriented toward middle scale surveys. The figures presented in table one are of course extrapolated from our existent cameras.

3. THE SURVEYS REALISED

Two surveys have been realized with the 96 camera, one in winter over the city of Amiens in the north of France and one in summer over the city of Lyon. The 97 camera is yet (in July 1997) to be tested in flight, as soon as the weather will permit. One of the advantages of digital cameras is that they are much more sensitive than films and that their response is linear to light. So, compared to film-based cameras, they can be used in a wider range of light conditions. It was the motivation of the flight in January. Moreover, and for the same reasons, the dark levels in shadowed areas are also better represented in digital images than in films. That was the motivation for the flight in summer, where the shadows are more contrasted and relatively darker than in winter.

3.1 The Amiens survey

It has been realized in January 96 around 1h PM. The main survey has been done at a flight level of 2000 m. With the lens used and the sensor pixel size of 9 µm, the ground pixel size is therefore 75 cm. About 70 images have been brought back from this first test. The winter light has imposed a relatively long exposure time of 50 ms. So, the forward motion compensation has been done for 5 pixels. In winter, small surfaces directly exposed to the sun are very bright, but most of the scene is shadowed. Therefore, the images in winter have an unusual aspect (Thom, 1996).
Anyway, in these conditions, the images are of good quality, even in the shadows. Usually, the scanned images used in IGN have a ground pixel size of about 40 cm, but these digital images with their 75 cm ground pixel size were judged quite "plottable" by the operators. This highlights that good radiometric performances can partly compensate for a loss of geometric resolution.
Another conclusion is that 12 bit pixels are necessary to preserve a good Signal / Noise ratio especially in the shadows, where the light level is about 15 times less than in bright areas. A problem then arise from the fact that the dynamic of output devices such as CRTs or plotters does not allow this kind of resolution. We have then to use different sort of processes to enhance the dynamics in the shadowed areas, such as dynamic look-up table adaptation on screens, or gamma transformation on printers.

3.2 The Lyon survey

The main goal of the Lyon survey was to prove that in a dense urban area and in July, at 11h am local solar time, with a particularly good weather (the worst conditions for shadows), the digital images were

also of good quality, and especially information could still be extracted from shadows. Two surveys have been realized, one at 1000 m with the 24 mm focal length lens, i.e. a ground pixel size of 40 cm, covering an area of about 1.2 x 6 km^2, and one at 1600 m, i.e. a ground pixel size of 60 cm, covering an area of about 7 x 11 km^2. For the middle scale survey, another strip has been done over two previously surveyed strips to test multi-stereo correlation algorithms for DEM extraction and building modeling. About 200 images have been brought back.
A mosaic of orthophotos has been realized with 9 of those images at the ground pixel size of 60 cm. At this occasion an automatic aerotriangulation has been realized. This operation on these particular images has been realized without showing problems that could be due to eventual deformations of the sensor. The lack of a sufficient number of ground control points has unfortunately prevented the self-calibration of the camera.

3.3 Comparison winter - summer

The images in winter and in summer have been compared in dense urban areas, the result is presented on the following histograms of the grey levels in image extracts.

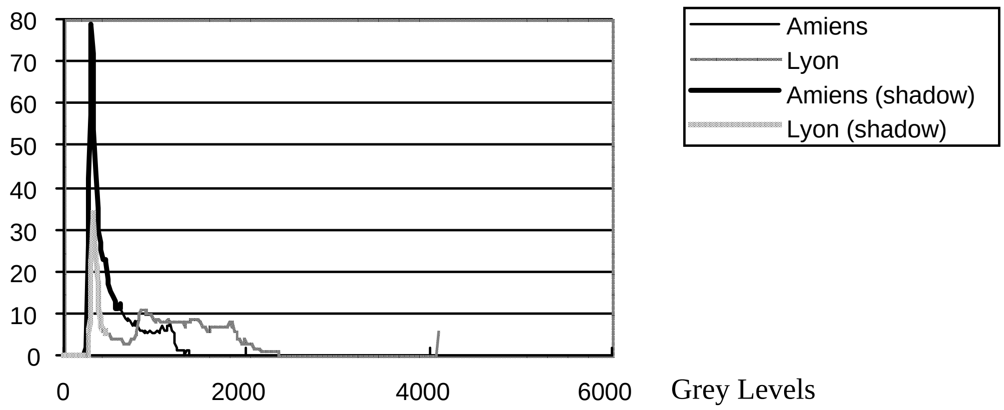

Figure 2: Histogram of the Grey Levels in Two Sub-Images of Dense Urban Areas (Amiens in winter and Lyon in summer).

The winter conditions, if they are difficult from a certain point of view (e.g. long exposure time), are, for some other aspects, favorable: e.g the shadows are, of course, less dense than in summer and the information contained in them is therefore easier to detect. In fact, in winter the number of grey levels used to represent the shadowed areas is 2 or 3 times greater than in summer. This has to be tempered by the fact that the number of pixels that are in shadowed areas are also 2 or 3 times greater.
This of course could be completely predicted from simple physical and geometrical laws, but these surveys are a practical approach to judge if winter surveys over urban areas with a digital camera could be realized for production purposes. Today almost all surveys are realized in summer, with the problem that shadows are very deep and that it is difficult in these conditions to extract information contained in those areas (e.g. street borders or lines when the street is narrow and between two rows of high buildings). Operators, when presented with winter images, thought that there were quite exploitable despite their unusual appearance.
Figure 3 below presents an equivalent dense urban area, in winter (left) over Amiens and in summer over Lyon. The ground pixel size is 75 cm in the Amiens image and 60 cm in the Lyon image. The display histograms have been adjusted to reduced the density of shadowed areas. Without this artifice, these areas would have appeared completely black on both images. One can also notice in these images

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(Lyon for example, with a ground pixel size of 60 cm), that details smaller than the pixel size but contrasted could be well distinguished, e.g. street lines.

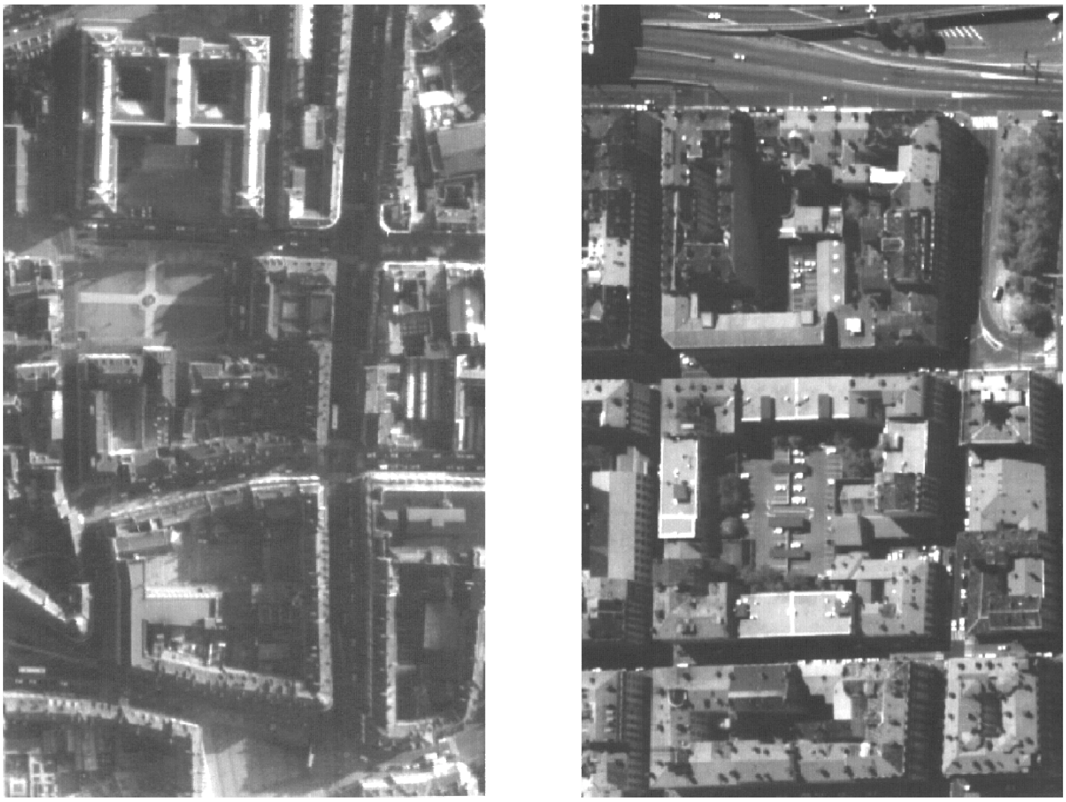

Figure 3: Comparison of the Aspect of Images in Winter (left) and in Summer (right).

Figure 4 presents images for which the information contained in shadowed areas is emphasized. This allows for seeing the areas at the foot of the two respective cathedrals of Amiens and Lyon Saint Jean.

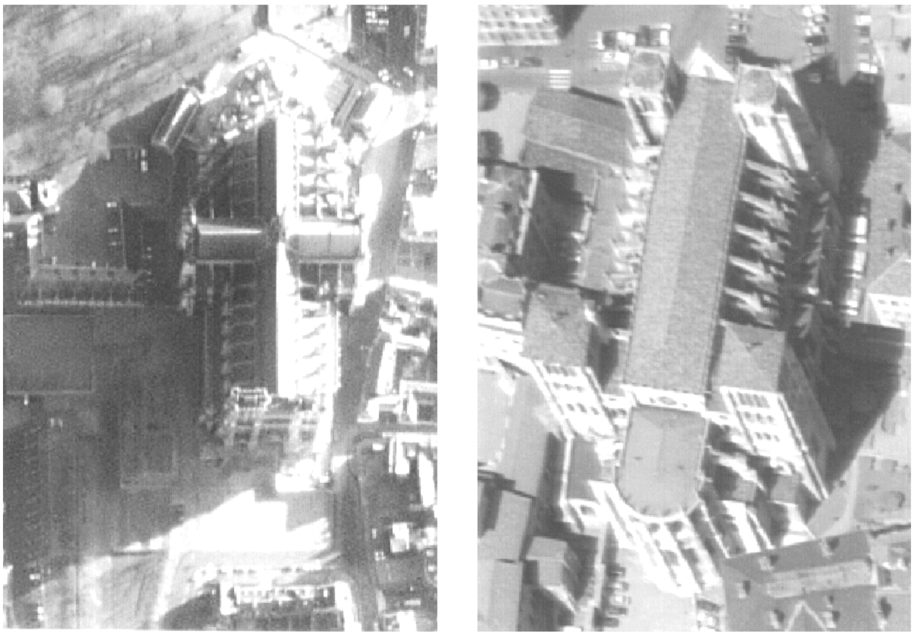

Figure 4: Shadowed Area of Amiens cathedral (left, 75 cm) and Lyon Saint Jean cathedral (right, 40 cm.

It is obvious on these images that the information contained in shadowed areas is easier to extract in winter than in summer. Since the sensitivity of digital cameras allows for winter surveys, the usual habits should be changed to fully profit of the best conditions to realize certain type of surveys where shadows could be a problem, like production of orthophotos in dense urban areas. Work has been engaged at IGN in collaboration with the Ecole Supérieure des Géomètres Topographes to compensate for the shadows using a DTM and a DEM of the built areas to compute the shadowed parts of the image.

4. THE PRODUCTION PERSPECTIVES

The main goal of IGN is of course to use digital images for production. There are several fields where digital images could be used :

- Digital orthophotos. This market is today in increasing development, especially for GIS and town management. In this case, the images must preferably be in color. We dispose now of a color sensor that will be tested in flight during the summer 97. The study about the removal of shadows mentioned above will also improve the display quality of digital ortho-images. Once again, due to the better Signal / Noise ratio, the final result should be better with digital images than with scanned films. The quality of the result might compensate for the increase of the flight cost.
- Production of the BD TOPO®. A few integrated production lines are already digital and therefore use digital images. Most of these images are for the moment scanned films. But since direct digital images have a better radiometric quality, one present way of development is to use our cameras' aerial digital images in these particular production lines. In order to be more competitive in front of film-based cameras, the camera that will be used will be equipped with a 4096 x 4096 pixel CCD sensor to produce images about 2.5 times greater than with the 3072 x 2048 pixel sensor ; it will lead also to a better B / H ratio (B is for base, that is the distance between two adjacent stereo images, typically 0.4 x ground image size, and H is for flight height), and to fewer images, easing the stereopreparation and aerotriangulation process. The tests done in the digital production lines highlight the fact that the fairly good Signal / Noise ratio of a digital images could partly compensate for a loss of geometric resolution. The 45 cm ground pixel size of the scanned images will then be replaced in the digital image with a value of 60-80 cm. Unfortunately, our stereo-plotters cannot point details under the pixel accuracy level. The images will then be over-sampled two times to attain the altimetric accuracy needed for the specifications of the BD TOPO®. As an illustration of this problem, see Figure 5 showing at the approximative scale of 1 / 1000 an extract of an image with a pixel size of 40 cm. The image has been over-sampled two times and then enhanced.
- Digital elevation model of urban areas to determine propagation maps for telecoms.
- Updating of GIS when small area are affected, e.g. construction of a new road, housing developments, etc.

5. SURVEYS PLANNED FOR 97

Two surveys are planned for 97. The first will target urban products such as those mentioned above: orthophoto and DEM. An overlap of 60% will be used in all directions : along the strip and across. Every point on the ground will be visible on at least 4 images, making it possible to use multi-correlation ; it will also greatly limit the quantity of masked areas. It should result in a orthophoto of great quality. During the same flight the color camera will be tested on the same area.

The second will be used to produce a BD TOPO® map sheet. The 4096 x 4096 sensor will be used. It will be the first real production done with our camera.

Figure 5: Extract an image over Lyon at the approximate scale of 1/1000. The ground pixel size is 40 cm. A gamma transformation was used to enhance the content of shadows.

6. CONCLUSION

First tests of IGN new camera have confirmed the good quality of the produced images. The benefit is such that it could partly compensate for the smaller size of the sensor with respect of the traditional cameras. The dark shadowed areas are now exploitable, with of course a suitable processing of the images. The remaining questions about the profitability of the use of the aerial digital camera to produce topographic data will soon be given an answer, with the carrying out of a survey in real size

for the BD TOPO® production. The production of orthophotos, that has been stemmed until now by the lack of color, can start now with the use of the color camera..
Aerial digital cameras will be the indispensable sensor as a complement to the future high resolution earth observing satellites that will launch for good the use of digital imagery in the cartographic field.

7. REFERENCES

Thom, Ch. and I. Jurivillier (1993): "Experiences with a digital aerial camera at Institut Géographique National (France)", Photgrammetric Week '93 , pp. 73-83, Fritsch / Hobbie Eds.

King, D.J., Armenakis C. and A. Chichagov: "The Use of Airborne Digital Frame Camera imagery for DEM Generation", Geomatica, Vol. 49, No 4, pp. 489-497.

Mills, J.P. and I. Newton: "A New Approach to the Verification and Revision of large-scale mapping", ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 51, pp. 17-27.

Bobbe, T. and P. Greenfield (1996): "Applications of Natural Color and Color Infrared Digital Cameras as a remote Sensing Tool for Natural Resource Management", In Proceedings of the Second International Airborne Remote Sensing Conference and Exhibition, ERIM, Vol. II, San Francisco, pp. 301-305, 24-27 June 1996.

Thom, Ch. and I. Jurvillier (1997): "An Aerial Digital Frame Camera for Photogrammetry : Radiometric Comparison with Scanned Imagery", Geomatica, Vol 51, N° 2 (1997), pp. 133-141.

Jurvillier, I. and Ch. Thom (1996): "IGN New Aerial Digital Frame Camera for Photogrammetry", In Proceedings of the Second International Airborne Remote Sensing Conference and Exhibition, ERIM, Vol. II, San Francisco, pp. 156-164, 24-27 June 1996.