Shuttered Camera — Aerial Color Video Imaging in the Visible and Near Infrared

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ABSTRACT: Oblique video imaging equipment was constructed which is suitable for large scale forestry surveys from light aircraft. The usual configuration consisted of a narrow-angle shuttered camera for the detailed survey and a wide-angle camera centered on the same area for location determination. The shuttered camera was either a normal color video camera or a specially constructed near-infrared camera recording in both red and infrared channels. The composite video signal from a still image could be digitized after transforming it to an RGB signal with a syncrhonization pulse with each color. Larger scale oblique or vertical imaging is suitable for assessing forest damage. Smaller scale imaging, when combined with more detailed imaging, could be used for mapping. Interpretation techniques and numerical processing still need much development.

INTRODUCTION

AIRBORNE VIDEO IMAGING will probably spread rapidly in the foreseeable future due to its low cost, flexibility and the capability of overlaying verbal information on the image. The advantages and disadvantages in comparison with aerial photography are itemized on Table 1 (Meisner and Lindstrom 1985).

The aim of this study was to develop video imaging equipment which would meet the needs percieved for forest damage assessment, forest management, and general mapping applications. Two camera systems were developed and tested: an oblique system which could be easily installed and removed from a light aircraft, to be used primarily for forest surveys, and a vertical system for general forest inventory and mapping. A digitizing module capable of producing multichannel imagery from a color composite for use in numerical processing and interpretation was an essential component of the equipment.

EQUIPMENT

IMAGING EQUIPMENT

Three shuttered solid-state color video cameras were used:

- 1. Xybion model SVC-09 S/N 3602*
- 2. Panasonic WVP-F10
- 3. Color infrared camera (developed for the project)

A fourth camera, a Hitachi VK-2000E with no shutter, was used for location determinations.

Because the spectral range of the solid-state sensor includes the near infrared, it was possible to build a color infrared camera with existing components. Video imaging systems based on black-and-white tube cameras, operating in the near and middle infrared, have already been used (Everitt and Nixon, 1985; Richardson *et al.*, 1985; Nixon *et al.*, 1985; Everitt *et al.*, 1986a and b). Meisner and Lindstrom (1985) have described a color infrared tube camera.

*Description and use of the equipment does not constitute endorsement.

TABLE 1. COMPARISON BETWEEN AERIAL PHOTOGRAPHS AND VIDEO IMAGES.

Aerial photographs		Video images	
positive	negative	positive	negative
High spatial resolution			Weaker spatial resolution
	Spectral resolution quite weak, the whole spectral range in a single image	Possible range up to near IR, three spectral channels can be distinguished with an RGB-converter	
Easy to make paper copies		Images can be interpreted with an ordinary TV monitor	Difficult to obtain satisfactory paper copies (video printers are being developed)
	Digitizing complex	Digitizing of still pictures easy	
			Picture motion necessitates a shuttered camera when the imaging scale is large
3-D interpretation easy			3-D interpretation requires special equipment or paper copies
	Success can be determined only after the development	Success can be determined in real time	
	Difficult to add other information during imaging	Verbal and other information can be added during real time	
Films and black and white prints store well			Storage of tapes uncertain
	Picture cost high	Picture cost low	

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The stable geometry of the solid-state sensor is an important factor in applications related to mapping, where digitized images are corrected to a map coordinate system (King and Farrier, 1981; Meisner, 1986).

The Xybion camera, built on the body of a Hitachi VK-C2000E video camera, had an NPN three-layer MOS Image Sensor element of 377(H) by 577(V) pixels, covering the spectral range of visible light. A Canon 8× TV Zoom lens (11.5mm to 90-mm focal length *f*/2) was used most often for oblique work, and a wider-angle 7.5-mm focal length lens (*f*/1.4) was used for low altitude visual observation from a helicopter. Mechanical shutter speeds between 1/500 sec and 1/10,000 sec were available, but under normal daylight conditions 1/500 sec or 1/1000 sec were found appropriate.

The Panasonic camera had a spectral range similar to that of the Xybion camera but used a 2/3" CCD element with 574(H) by 581 (V) pixels. The camera had an electronic shutter with a fixed exposure time of 1/1000 second and was used with a 12× Studio zoom lens WV-LZ15/12 (10.5 to 126-mm, focal length *f*/1.6). With the gain device employed, the minimum illumination required for this camera is only 10 Lux.

The color infrared shuttered camera was also built on the body of a Hitachi VK-C2000E camera and used the same Zoom lens as the Xybion camera. The composite video signal from this camera was made up of a red component representing red light and a green component representing the near infrared radiation. The signal could be recorded and viewed normally or used as a source for a digital two-channel image.

Two Panasonic NV-180 VHS recorders were chosen because of their portability and good still frame performance. Either Ni-Cd batteries or the aircraft's own power supply were used as a power source.

Installation of the Equipment

Installations for oblique imaging were made in three types of aircraft: a Cessna 172, a Piper Lance, and a three-seater Hughes helicopter. In the Cessna, both a shuttered camera and the position-recording Hitachi camera were mounted on a tripod such that they viewed through an open window to the side and front. An extra telescopic tube anchored between the tripod and the ceiling ensured additional rigidity for the tripod. The front right seat was removed in order to provide space for the recorders and monitor in their padded box. In the Piper Lance, the door was removed and the imaging equipment was fixed to the door opening, with the cameras pointing directly to the side or slightly backwards. The installation is illustrated in Figures 1 and 2. For imaging from the helicopter, the Xybion camera was clamped to the upper part of the undercarriage and the other equipment was placed inside on the floor.

A three-seater military training Vinka aircraft was used for vertical imaging. Both the Panasonic and color infrared cameras were installed directly over two holes in the floor of the aircraft for simultaneous imaging.

Fig. 1. Installation of the equipment for oblique imaging in a Piper Lance aircraft.

EXPERIENCE

Operational Configurations

Nine trials have been carried out thus far for forestry and mapping purposes at altitudes ranging from one metre (helicopter) to 1,000 metres. The weak spatial resolution of the video images results in the need for using either long focal length lenses or low flying heights in order to obtain necessary image detail. Tests showed that detailed imaging of tree crowns could be achieved by using a 45 degree viewing angle and an image width that was not greater than 15 m. This enabled individual branches to be observed (Figure 3). In such detailed imaging, the use of a wide-angle camera like the Hitachi is essential for determining location.

In the case of vertical imaging, it was found that the image width could fall between 70 and 100 metres and single young trees could still be detected. This was adequate for forestry regeneration and treatment assessments, as illustrated in Figure 4.

In testing the mapping capabilities of the system, it was found that, by imaging from an altitude of 1000 m with a vertical camera having a lens-angle of 60 degrees, the main features of the area, roads, new buildings, etc. are still detectable. However, in order to identify targets, a scanning camera having a 5 degree field of view (90 m) and covering the whole area is required.

Resolution

A rough estimate of the resolution of the system was made by imaging a high contrast test chart consisting of horizontal and vertical lines (Dyall, 1978) which was illuminated by a 800 W halogen lamp located three metres from the chart. Using the 8× zoom lens on either the Xybion or Panasonic cameras gave a value of approximately 320 lines horizontally and 330 lines vertically when observed on the television monitor. The 12× zoom lens used with the Panasonic was somewhat lower at 280 lines and 300 lines, respectively. Recording the signal tended to decrease the horizontal resolution in particular. The total number of separated horizontal and vertical lines is similar. The remarkable lower horizontal resolution results from the image width to height relationship which is 4:3.

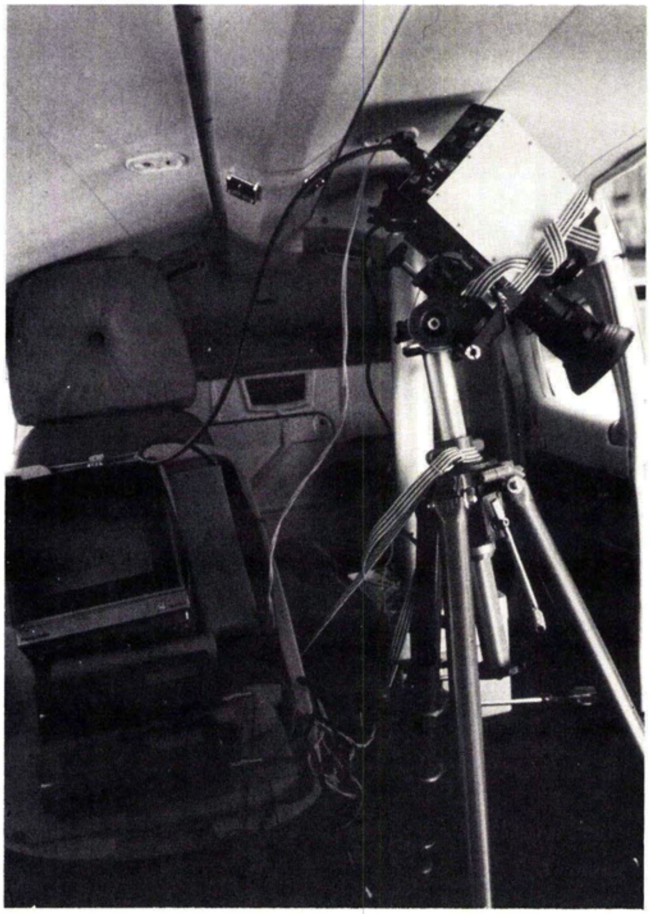

FIG. 2. Recorders and monitor packed into a padded box.

FIG. 3. Oblique low altitude image. In front, damaged spruce trees. Cessna aircraft, Xybion camera.

If the shorter side of the image is chosen parallel to the flying direction of the aircraft and image motion is limited to one resolution unit (Meisner, 1986), then with a vertical resolution of 250 lines and an aircraft ground speed of 150 km/h, the shorter side of the image can be as small as 10.5 m on the ground. Under these conditions the sharpness of the image is still satisfactory although not excellent. Turbulent air, however, can cause image motions greater than that due to forward image motion alone.

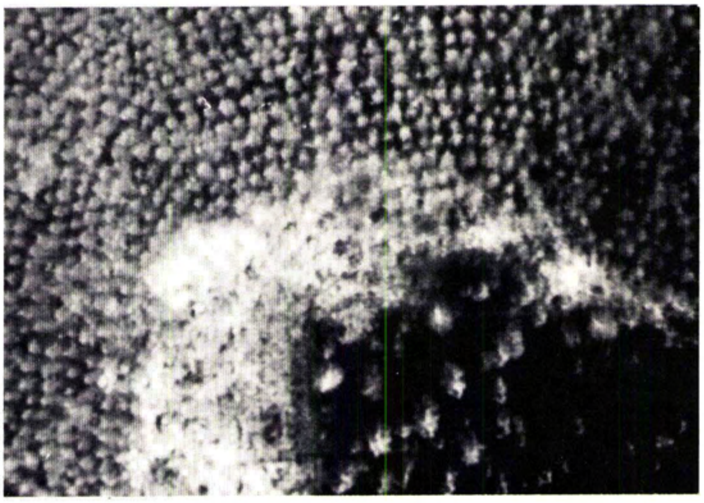

FIG. 4. Vertical low altitude image. Old spruce forest and a pine plantation. Image width 80 metres. Vinka aircraft, Panasonic camera.

EFFECT OF WEATHER

Hazy weather or bright overcast, with a good deal of scattered light, seemed to afford the most suitable conditions for low altitude imaging. The exposure tolerance of the Xybion camera was narrower than that of the Panasonic and, under clear conditions, lacked detail in the shadows. Although the sensor of the Panasonic camera was such that imaging was possible under very poor—even rainy—conditions, the low contrast and the modest spatial resolution made interpretation of the images difficult. The color infrared camera produced images of high contrast and, therefore, worked reasonably well even in poor conditions.

Manual setting of the diaphragm based on exposure determination using the monitor could result in overexposed images even though the face of the monitor was shaded by a sun visor. Nevertheless, manual setting is preferred to the automatic adjustment of the exposure.

DIGITIZING AND DIGITAL PROCESSING

The still images were digitized using an Intel-Salora image processing system of the Technical Research Centre of Finland, and some processing was carried out on a VAX 11/750. The aim of digitization was to build equipment with which the composite video signal from a still image could be transformed to an RGB-signal with a synchronization pulse with each color. It also made possible preliminary comparison of the video images with satellite scanner images. Plate 1 shows two channel imagery from the color infrared camera.

The number of intensity values of a digitized video image was over 250 values per channel; however, this large number was caused largely by noise and striping in the image, which were increased by the digitizing process.

As in the case of digitized aerial photographs, digital image analysis was made difficult by the variation in spectral values between the front-lit and back-lit sides of a wide-angle image. Scale changes due to tilt and elevation differences can also make it difficult to combine images into digital mosaics.

Figure 5 shows the detection of textures in forested areas. Image segmentation using the directed trees method described

PLATE 1. Digitized color infrared video image. Areas of vegetation (coniferous forest and part of an agricultural field) appear green. Area 500 metres by 500 metres. Vinka aircraft.

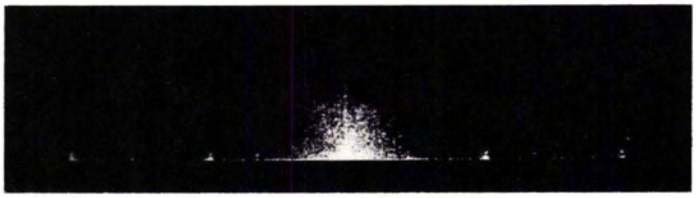

FIG. 5. Fourier transform of the red light channel of the color infrared video image. The dots along the horizontal plane refer to the striping in the scanning direction. The vertical line indicates that the original image also has vertical striping of various frequencies. The surroundings of the zero harmonic term (origin) show that there are directed formations because there are only a few values in some directions and peaks in others. The most noticeable peaks may be caused by the shadows of conifer crowns.

color infrared image, but the tree crowns and the shadows between the crowns were outlined as segments within stands. The use of this method, which works well with Landsat TM and SPOT data for the interpretation of stands, is not adequate for use with video images of higher resolution.

CONCLUSION

The development of easily portable and readily installable video camera equipment, using shuttered cameras, was achieved. Tests showed its potential for detailed forest damage and treatment surveys and for data acquisition for general mapping purposes. Where some industrial forest companies in Finland now carry out inventories by helicopter using tape-recorded verbal estimates of the values of the stand variates, the equipment described could provide a visual reference record of the forest as well the verbal one.

Several improvements to the system are needed. The location of the narrow-angle camera frame should show in the wide-angle positioning image, interpretation equipment for analogous images needs development, and digital processing and analysis is as yet very primitive.

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