PHOTOGRAMMETRIC COLOR SCANNING

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ABSTRACT:

Scanning of analog image material remains a key function in the photogrammetric production chain as long as digital aerial cameras have not completely taken over. Therefore it remains an important goal to achieve optimum scanning results. This contribution reviews how the scanning procedures have evolved since 1990, compares photogrammetric and non-photogrammetric scanning applications and focuses on the scanning of color material. The implementation of such concepts is presented by several examples, including the need for color calibration.

1. FROM CENTRALIZED SERVICE TO DISTRIBUTED FUNCTION

After an initiation in about 1990, photogrammetric scanning by now has become a routine and standard element of each digital photogrammetric workflow (Baltsavias & Kaiser, 1999; Leberl et al., 1992). Initially, the concept was to set up scanning service bureaus, which would centralize the scanning function for many photogrammetric mapping workshops. But since the photogrammetric equipment manufacturers were able to develop increasingly more affordable products the scanning function has become very distributed and has been brought into each photogrammetric operation. This improves the workflow and offers the photogrammetric production managers complete control over the end-to-end workflow for extraction of information from blocks of initially analog photography. The photogrammetric industry has come back to a situation that existed when analog and analytical technologies "ruled", with a clear interface between the raw data creation by means of aerial photography specialists, and the information extraction by photogrammetric processing specialists.

2. PHOTOGRAMMETRIC VERSUS NON-PHOTOGRAMMETRIC SCANNING

However, bringing the scanning function into a photogrammetric mapping operation has led to a need to better understand the workings of scanners on a routine basis. "Document scanning" is a rather traditional function in industry with many different manifestations. There are the color graphics and printing industries with their need to change a color photograph into separate cyan-magenta-yellow-black channels for offset printing, producing the justification for the largest investments in scanners compared to other industries. Since about 1990, this has been changing over from a simple task of color separation into an input to digital image processing systems (see figure 1). There is medical scanning of X-ray films and of histological specimens. The manufacturing industry has for several decennia studied the need to convert paper drawings into CAD-documents. And the most recent developments have been inspired by the transition to the "paperless office", leading to the need for low cost, low quality scanners in each office. Today, millions of scanners are being produced each year as peripherals to personal computers.

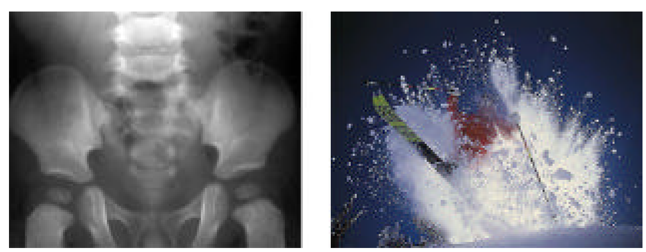

Figure 1: Non-photogrammetric scanning examples. Left is a medical application (x-ray, monochrome, up to 4.0 OD) and to the right a graphic arts application with a wide dynamic range.

In this context, photogrammetric scanning is a niche with very distinct requirements which are set apart from all other scanning applications, first and foremost by the need to offer a

1. high and well defined and verifiable geometric accuracy.

In analogy to photogrammetric coordinate measuring equipment, this accuracy is typically seen in the range of ± 2 µm. Other specifications typical for photogrammetry exist as well, to include the need to work with

2. a comparatively large format at 25 cm x 25 cm (Fig. 2);
3. transparent film;

4. uncut and rather heavy rolls of film;
5. comparatively large data quantities, given 23 cm x 23 cm color imagery and small pixels;
6. high geometric resolution of up to 5000 dpi.

Figure 2: An aerial image, 23 cm by 23 cm, results in a digital file of several hundred megabyte of data (e.g. 705 MByte @ 15 µm pixel size and 3 by 8 bit color depth)

While some attempts have been made to convert graphic arts scanners into photogrammetric systems, these have generally not been successful, except where the application was for low quality ortho-photo production (Thorpe, 1992). Today it is generally understood that the needs of the photogrammetric application can only be met by specialized scanning systems.

3. NEED FOR HIGH RADIOMETRIC PERFORMANCE

Converting analog film into digital information requires the ability to resolve the radiometric range of the film (Kölbl, 1999; Neumann & Baltsavias, 2000). We know from densitometric measurements that b/w film material may cover a dynamic range from approximately 0.1 D up to 2.5 D, perhaps up to 3.0 D in special cases (Fig. 3). Investigating color dia-positive material one may need to coop with an even larger dynamic range, e.g. up to 3.5 D.

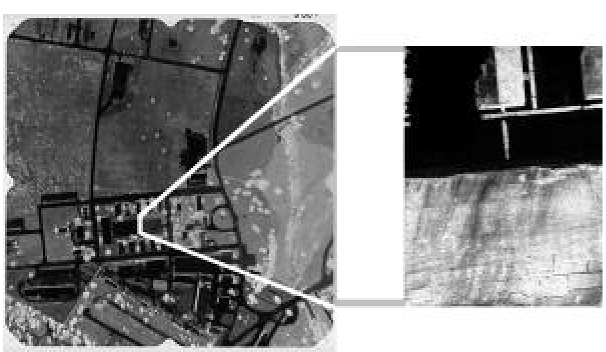

Figure 3: B/W negative aerial frame with a large dynamic range of 3.1 to 0.3 D. Details like cracks in the asphalt are clearly visible in the digital image after radiometric enhancement of the image detail.

4. THE NEED FOR COLOR

When photogrammetry was based on analog measurement devices, color was a factor of extra costs when copies had to be made for work and finally color was expensive and critical in the analog production line. This has no longer any meaning in the digital photogrammetric workflow. Therefore the color information of photogrammetric products is highly appreciated. Scanning color images has become an every day job and photogrammetric scanners need to support the operator through a smart user interface and to show the technical ability to transfer color information from the analog film to the digital file.

5. DIGITAL WORKFLOW FAVORS USE OF COLOR NEGATIVES

Color negative film has become the media of aerial photography. Not as critical against exposure setting and light conditions like dia-positive materials this film type has become the favorite medium. The transition of this film to a digital format is the issue of modern photogrammetric scanning. We show with the example in Fig. 4 how masked color negative film is presented in a raw format, and how problematic images can be managed. While the use of negative film adds cost in an analog workflow, if does not add cost in a digital work flow.

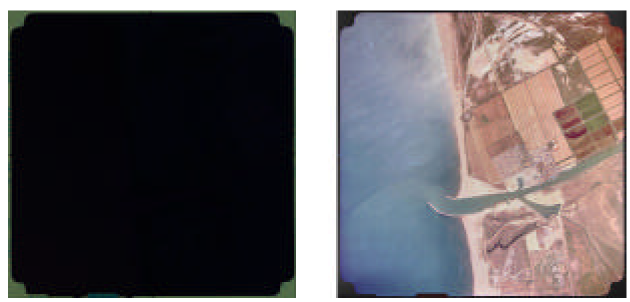

Figure 4 at left is a color negative aerial frame with the dynamic range at 2.8 to 1.1D including the effect of a “masking layer”. The image quality is acceptable after image enhancement (right).

6. COLOR CALIBRATION

In the beginning of photogrammetric scanning the calibration of the geometry of a scanner was most important. This was followed by the realization that the radiometric calibration is important as well, and one became concerned with the radiometric behavior of a scanner.

The most recent issue is the calibration of the color response of a scanner. This will provide full control over the digital workflow and make color management possible. Known from graphic arts these so-called “color profiles” need to be produced by scanning a specific color target and need to get then added as collateral information to the output image data.

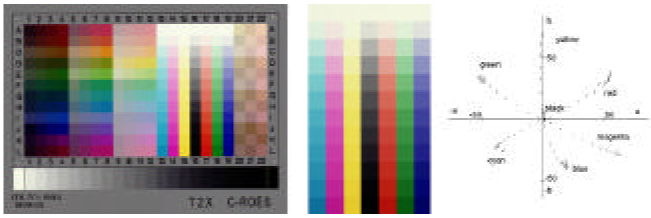

Figure 5: The IT8 color calibration target is used to control the radiometric performance of a scanner. Left: full target, showing 246 color tags and 24 gray scale tags. Middle: the 6 primary colors and black from the completed target. Right: Transform of measured color values from a scanner and reference values from the calibration target .

Figure 5 illustrates a color calibration target and a 2D color space showing the theoretical and scanned positions of the various colors. Differences can be corrected via a look up table.

Medium-independence: Color calibration may serve to obtain the same color *on each medium,* beginning with the film source, proceeding via a display monitor to the hard copy output, for example as an ortho-photo.

Automated interpretation: Color calibration may also be used to support the *automated interpretation* of images. Image segmentation based on color needs to employ training data. Color of a specific object in the terrain should be carried through the workflow.

Scanner independence:
Finally, the color of a film source should always come out with a scanner-independent triplet of R-G-B-numbers, thus irrespective of the specific scanner used.

7. A LOOK AT GEOMETRIC DETAILS

We show some results and practical experiences from scanning with the photogrammetric scanner UltraScan5000. Color calibration was illustrated in Figure 5 and explained in the previous section 6. Another example shows the well known US-Airforce Target, scanned at a resolution of 5080 dpi (5µm pixel size), and showing that the appropriate pattern indeed has been resolved (see also Gruber & Leberl, 2001). Another example shows a part of the high resolution color negative film Agfa X100. The granularity of this film comes close to that of well known B/W material like the Kodak Panatomic X (Fig. 7).

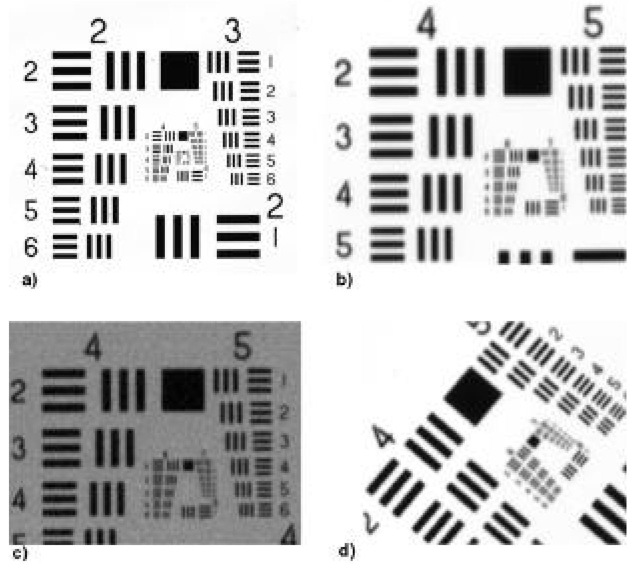

Figure 6: The US-Airforce Resolution Target. (a) entire target, (b) central part, showing the resolved pattern of section 6.1, (c) same as (b) at a lower dynamic range and (d) target scanned at a rotation angle of 45 deg.

8. CONCLUSION

We argue that photogrammetric scanning continues to be an important element of an end-to-end digital work flow. It is changing from a centralized service bureau function into a distributed and integrated function of that work flow, at the photogrammetric specialist’s office.

Color is playing an increasing role in photogrammetry. The analog color on a film needs to result in a triplet of numbers for the scanned imaged, independent of the specific scanner used. The color also needs to be perceived to be the same, whether it is presented on one or the other display medium or hard copy output. A complex issue is machine-supported photo-interpretation in which “color” is a feature of specific real-world objects. In this case the scanner becomes a physical measurement device with a requirement to produce accurate spectral information about imaged objects.

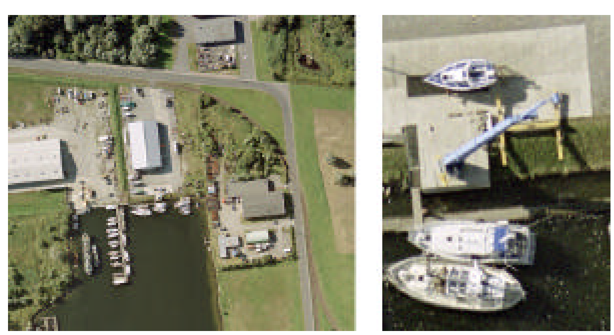

Figure 7: Aerial image taken at a scale 1:5000. The AGFA X100 color negative film shows a remarkably fine granularity and allows scanning at a resolution of 2500 dpi.

LITERATURE

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