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MENSURATION FRAME GRABBING FOR SOFTCOPY ANALYSIS OF FILM IMAGES

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ABSTRACT

Softcopy image analysis has numerous advantages in the area of automation that do not exist in analog hard-copy film analysis. However, the vast majority of source imagery is on film. This paper examines the various options that exist to convert film data into a pixel format for digital image processing. It argues that on-line frame grabbing offers significant advantages. We present a novel scanning concept based on an invisible very dense reseau. This permits one to scan large formats at small pixel sizes, leading to high accuracies.

1. INTRODUCTION

Automation opportunities have led to a dramatic increase in the use of digital image processing in photogrammetry and photo-interpretation. While most developments are based on analyzing imagery from digital sensors such as LANDSAT, SIR-B, SPOT and others, there is also an increased tendency to exploit film imagery by digital image processing technology. An example is stereo-correlation in analytical plotters such as discussed and implemented in the KERN Analytical Plotter DSR-11; and point transfer in aerotriangulation as presented by Pertl (1984), Foerstner (1984), Helava and Seymour (1987) and others.

Softcopy image analysis, when applied to film imagery, requires the scanning of the source material. This paper discusses the problem of scanning for precision mensuration, and presents a specific concept and its preliminary proof-of-concept implementation. It may be argued that the next generation analytical plotters will in fact be image processing work stations with film scanning peripherals.

It should therefore be evident that appropriate film scanning technology is of great relevance to photogrammetric instrumentation for the period of time where processing technology is digital, but image acquisition technology is film-based.

2. FILM VERSUS SOFTCOPY IMAGERY

2.1 Imagery

Table 1 lists the various considerations that are relevant in an assessment of the merits of film and digital sensing as well as film/analog versus pixel-array/softcopy analysis. We do understand the information content of film if it needs to be converted to an equivalent pixel array. As is commonly argued, and experimentally verified by Trinder (1987), more than two pixels need to be used to represent a line pair. The exact relationships are best represented by continuous modulation transfer functions. In a first approximation and for a wide-angle aerial camera at a format of 23 x 23 sqcm with 40 line pairs per millimeter we find an equivalent pixel array of 23,000 x 23,000 values or 529 MByte for a black and white photograph. In the event that color is used three grey values need to be stored with each pixel; thus 1.6 GByte would need to be available to represent the contents of the color photograph.

It is immediately evident that the aerial photograph is a powerful storage medium. Aerial photogrammetry with forward motion compensation results in resolutions of perhaps 60 or more lp/mm (Meier, 1984). Other film materials for reconnaissance imagery are at even higher resolutions in excess of 100 lp/mm, but at smaller formats, typically at 70 mm. Close range photography with metric cameras such as a Hasselblad, Rolleiflex or Asahi Pentax may represent 40 lp/mm over a 50 to 70 mm format, and therefore arrays of 5000 x 5000 pixels.

Digital imaging may produce large pixel arrays only if linear detector arrays are used and kinematic sensing is applied. This is common in reconnaissance, at the expense of high geometric fidelity. The use of square arrays is limited practically to 512 x 512 pixels at 30 hertz, or 1000 x 1000 pixels at 7 hertz (e.g. VIDEK, 1987). Larger arrays of up to 2000 x 2000 pixels have been discussed, but are not common at this time.

Table 1: Considerations relevant to film versus softcopy sensing and analysis technologies.

Spatial Resolution
Data Quantities
Geometric Rigor
Ease of Manipulation
Real-Time Aspects
Costs
Automation

Digital sensing is advantageous over film if a real-time application exists such as robot control, or if the kinematic mode of imaging is inherent to the sensor (SAR, multispectral imaging).

Other considerations between film and digital sensing may be convenience, cost and speed. This, however, needs to be judged for each application.

2.2 Analysis

Analog film analysis is an established, accepted technology and art. Softcopy analysis on a digital image processing workstation is new and not yet generally accepted; it is viewed as a remote sensing tool separate from photo interpretation and photogrammetry.

However, there are numerous advantages that become evident for softcopy analysis over analog methods. The major element is the opportunity to automate, or to support the interpreter/operator by machine processes. Examples are stereo-correlation, gray-value improvements, area counts, rectification, etc.

Other advantages may result from the ease of combining source materials such as images and vector data from a GIS (superimposition) , work with multi-dimensional data and, obviously, work with source material that is digital to begin with.

All this supports the claim that in many cases analog manual film analysis is technologically inferior to digital processing. However, the established tools are for film, and often no technological analysis aid is required at all, as in many photo-interpretation tasks in the field.

A major advantage of analog technology is stereo viewing. Binocular high-quality optical viewing systems produce a viewing comfort generally superior to softcopy stereo viewing of 512 x 512 or 1024 x 1024 pixel arrays. Softcopy stereo viewing has made significant progress in recent years but this still has not led to equivalence in comfort. It needs to be stressed that "comfort" is not synonymous with accuracy or precision. Computer support to stereo pointing can result in high sub-pixel pointing accuracies even in adverse viewing conditions (so-called tracking stereo -correlation). However, this opportunity does not seem to have received much attention.

2.3 Pointing Accuracy

A significant body of research exists on both the pointing accuracies in film images and on softcopy data. O'Connor (1962), Hempenius (1964), Trinder (1971, 1984) and others have established rules for manual pointing to symmetric targets in analog imagery. Hempenius (1964) provides a rule that an accuracy can be achieved of 5% of the target diameter and Trinder (1984) reports 1% to 2% of target diameter under exceptional circumstances. Typically, one uses in photogrammetry a measuring mark with 40μm to 60 μm diameter, and one may signalize significant object points or mark (drill) significant image points with 60μm to 100μm holes [1]. One expects to achieve a 2 to 3 μm measuring accuracy.

It has been rather revealing when analogous studies were made on manual and automated pointing to symmetric targets in digital pixel arrays. Early work was by Thurgood and Mikhail (1982), Foerstner (1985), Pertl (1984), Havelock (1984) and others. Rather than relating accuracy to target size, it has to be related to pixel size. Theoretical predictions lead to the conclusion that in noise-free images the symmetric target will be measured with errors of 1/50 pixel diameter.

[1] This is denoted by "pugging", from PUG, the German abbreviation of the device used for this task (Punkt Uebertragungs Geraet).

As the signal-to-noise ratio deteriorates, the accuracy is reduced as well and may go down to 1/4 pixel diameter. This advantage is clearly borne out in the accuracies reported from the AUTOSET system by Fraser et al. (1986).

Stereo pointing shows similar differences. Several authors have shown that matching of symmetric signals is also at very high accuracies. This is the rationale for automated point transfer in the work of Pertl (1984) and in the DCCS workstation of Helava Associates (Helava and Seymour, 1987).

3. FILM SCANNING PRINCIPLES

3.1 Off-line Systems

Table 2 presents an attempt at categorizing various film-to-pixel conversion schemes. The major grouping could be on-line versus off-line. In off-line systems, such as by Optronics, the pixel array is created independent from an analysis system. Various point-wise or linear-array implementations exist. Prominent among them are cartographic scanners for drawing conversions, and photo-scanners for the lithographic industry. Actual film scanning for mensuration is still uncommon and is used in the context of remote sensing studies. Single detector and linear detector array scanning are both available on rotating drums or flat bed devices. Products on the market are by Optronics, SysScan, Eikonix and others.

Table 2: Categories of Film to Pixel Conversion Systems.

A. Off-Line Scanners

- Drum Scanners
- Flat Bed Scanners
- Moving Spots
- Moving Linear Arrays

B. On-Line Systems

- Moving the Film
- Moving the Camera
- Reseau-Based Systems

3.2 On-line Systems

On-line scanning can also be referred to by "frame grabbing". A square or rectangular array of detectors is used to load an image segment into the refresh memory of an image processing system.

In most cases in the past, a Vidicon or CCD array camera is simply placed over an image. By manually placing the photograph in the camera's field-of-view one can obtain a small pixel array, but this does not lend itself to any meaningful mensuration work.

If geometric relationships need to be preserved in the digital recording then the film or camera need to be accurately placed with respect to one another in a comparator mode. The AUTOSET of Geodetic Services, Inc. and the DCCS of Helava Associates, achieve geometric relationships by precise mechanical motion. The optical system needs to be calibrated with a well defined optical axis. A zoom system is not available due to its effect on the geometry.

3.3 Reseau-Based Systems

To relax the sensitivity to environmental effects, to reduce demands on, and costs of mechanical precision, and to be free to implement a motorized zoom system one can enforce a rigorous geometry by a reseau. Wester-Ebbinghaus (1984) and Luhman (1986) have discussed a reseau-based on-line scanning concept. An implementation exists from Rollei Fototechnik in W. Germany. The reseau consists of black crosses on a glass plate put over the film emulsion.

The geometric resolution of the pixel arrays affects the instantaneous field-of-view. With pixel sizes of 4μm (Autoset) a 512 system has a 2mm field-of-view. The reseau-based system would need reseau crosses every 1mm in order to always have at least four reseau crosses in the field of view.

3.4 Invisible Reseau

With variable zoom and in photo-interpretation applications it becomes important to use a reseau that does not cover the image. Such a reseau is feasible and has been implemented in an on-line film scanning system by VEXCEL Corporation. Extreme pixel dimensions are 125 μm and 12.5μm, respectively, obtained with a motorized optical zoom system.

4. DISCUSSION OF RESEAU BASED SCANNING

The mensuration of image coordinates in a pixel array created by a reseau-based scanner has to consider a number of error sources not relevant in classical comparators. Table 3 is a list of such error sources.

Table 3: Error Sources for the Reseau-Based On-Line Film Scanning

A. Camera-Related
- Video camera read-out syncronization
- Optical distortion

B. Reseau-Related
- Absolute reseau location
- Reseau detection

C. Environment
- High frequency vibrations
- Temperature effects

Clearly there are environmental effects due to temperature changes that may affect the film. This is identical to conventional comparator problems. New problems relate, however, to the pixel readout from the CCD array or vidicon to the frame buffer, the accuracy with which the reseau marks can be recognized and the consideration of optical distortion since measurements are done in a 2-dimensional field-of-view by moving a measuring mark through a frozen frame.

In a large format of 10" by 20" the reseau calibration itself presents difficulties since such large format reference comparators are hardly available. However, this can be resolved in a bridging effort using a smaller format reference grid.

An interesting element in reseau based scanning is the possibility of using a motorized zoom system. This adds an element of complexity to the error analysis since reseau detection is dependent on pixel size, and distortion is a function of the zoom factor.

Figure 1 is the proof-of-concept film scanner based on an invisible reseau. Over a format of 10" by 20" the system uses 44,000 reseau crosses to support pixel sizes of up to 12.5 μm.

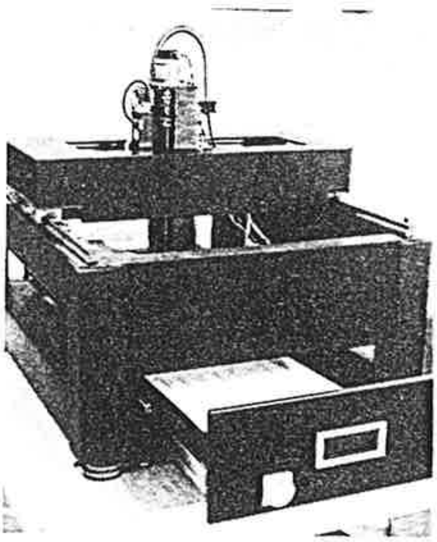

Figure 1: CPRIME film scanner

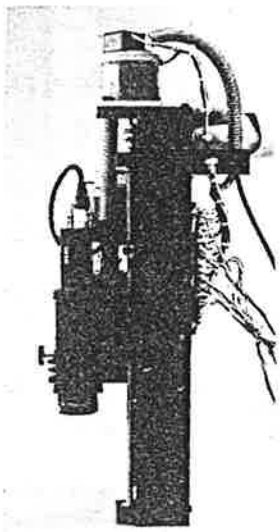

Figure 2: Motorized optical zoom system for CPRIME.

In essence, frame grabbing in such a system is done in a geometrically rigorously controlled manner so that measurements can be taken across the entire image format of 10" x 20" at very high accuracy. The user is meant to employ the film image as if a pixel array of 20,000 by 40,000 were on line in the image processing workstation.

We refer to this type of scanning therefore as "mensuration frame grabbing".

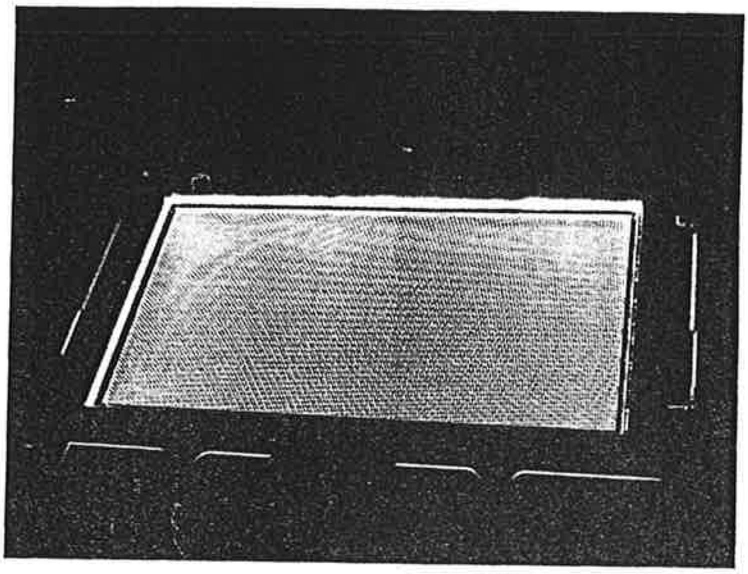

Figure 3: Reseau plate of 10" x 20" with reseau crosses.

5. CONCLUSIONS

We have discussed the need and importance of film scanning devices as add-ons to digital image processing systems. We expect that the next generation analytical instruments in photogrammetry will need to convert film images to pixel arrays for monoscopic and stereomeasurements.

The paper specifically addresses reseau-based on-line film scanning and highlights several advantages over on-line precision scanners that need to rely on optical-mechanical precision. Prominent among these advantages are cost, insensitivity to environmental effects and the applicability of motorized zoom optics.

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