EVALUATION OF DIGITAL CAMERAS FOR PHOTOGRAMMETRIC MAPPING

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ABSTRACT

A CCD digital camera with 2044x2022 pixels array was tested as an airborne imaging system for the purpose of metric mapping. The KODAK Mega Plus was flown at 6500 ft over an area in Desloge, Missouri. The digital data was then transferred to a softcopy photogrammetric station where digital aerial triangulation was performed. A digital elevation model was obtained from auto-correlation on some of the frames of the block and two-foot contours were generated and compared to the existing set of contours generated by conventional photogrammetry. Although the shapes of the contours generated by both methods seem to agree in shape and behavior, the results revealed a bias in the DEM obtained from the softcopy approach. The results strongly suggest the digital frame camera coupled with softcopy techniques are ready for photogrammetric mapping after an accurate calibration of the camera interior parameters.

1. INTRODUCTION

This decade witnesses the maturity of the digital frame camera (DFC) for commercial, industrial, and scientific photography. When we talk about DFC we specifically mean those cameras which carry the same configuration and concepts of the conventional film camera except in having a set of light sensitive devices or sensors called a charge-coupled device (CCD) arranged in a square or rectangular block called an "array", instead of the conventional film as a recording media. The advantage of adopting the geometry and the mathematical models of the current film for future cameras such as DFC is very appealing for the photogrammetric community as it translates into a shorter learning curve as the same concept of flight planning and execution will be employed with almost no change. This will multiply the return of our recent investment in softcopy systems, as the DFC will be adoptable by the recent soft copy system without any modifications or new mathematical modeling.

The DFC in general has some advantages over the current film camera as it has better geometric stability when you consider the deformation in the film of the film camera, better radiometric image quality and dynamic range, and capability for real time in-flight viewing (King, et al.. 1994). Only in the last few years have we witnessed the development of the DFC for productive system in remote sensing for qualitative measurements of natural resources. Very few of these systems exist in the commercial market today and among them is the system developed by Positive System and the USDA Forest Service (T. Bobbe, et al. 1994). When it comes to the use of such systems for photogrammetric mapping, only a few attempts have been made to question the capability of such cameras for photogrammetric mapping. King and his colleagues did the most in this field (King, et al. 1994, 1993, 1992).

King's research showed satisfactory results although the investigation was performed on one single model and did not take into consideration the stability of a traditional block photographed by the DFC. The paper presents the methodology and the results of a complete photogrammetric project from start to finish using soft copy techniques, i.e., DFC and softcopy data collection and processing in order to evaluate the feasibility of using DFC for aerial mapping.

2. METHODOLOGY

2.1 Digital Frame Camera System

Daedalus Enterprises, Inc. Of Ann Arbor, MI developed a pioneer complete digital aerial imaging system (Model AA455) which incorporated a Kodak MEGAPLUS 4.2 camera with 24 mm lens, a camera head control chassis, and a system recording chassis contained within a "lunch box" style computer. The Kodak MEGAPLUS 4.2 uses an array of 2029x2044 charged coupled devices (CCD) and a 24 mm lens, which provide a 40° Field of View (FOV). The system is strictly designed as an airborne system, therefore, it is provided with a mounting frame similar in size and dimension to the size and dimension of the aerial camera hole on the airplane. The camera has the capability to record a black and white (gray scale) image every 10 seconds which is the time required for the frame grabber to empty the signal from the CCD and store them on digital recording media on the airplane.

2.2 Mission planning

Given the 40° FOV of the lens and the fact that in 10 seconds, the airplane at 120 mph speed will travel the base distance (B) of 1760 feet, the following calculation which was based on sixty percent end lap was possible:

Frame ground coverage (GW) = 1760/0.4 = 4400 feet

Recommended average flying height (H) = 0.5 GW/tan20 = 6044 feet

Thirty percent side lap between alternate flights = 0.3 x 4400 = 1320.0 feet

Pixel ground resolution = 4400/2000 = 2.2 feet

B/H = 1760/6044 = 0.3

In order to have a priori estimate for the contour interval possible with the digital camera at the calculated parameters the following photogrammetric criteria were utilized (Light, 1990)

$$\text{Pixel size} = 1/K \times B/H \times \sigma_h \qquad (1)$$

where:

K = non-dimensional number expressing the degree to which stereocorrelation can be achieved. (Typical bounds for K are $0.2 \leq K \leq 1.5$)

σ_h = precision of a single height observation which is assumed to be one third of the contour interval (CI) ($\sigma_h = 1/3(CI)$).

B/H = the base to height ratio.

Substituting B/H=0.3 and K=0.3 (or the parallax errors=0.3 pixel size) in equation (1) will result in the following value for CI.

$$\text{Pixel size} = 1/0.3 \times 0.3 \times 0.3 \times CI =$$
$$\text{or } CI = 2.2/0.3 = 7.3' = 2.2\ m$$

This figure served only as a priori estimate but the possible contour interval should exceed the expectation.

2.3 Data Acquisition

The digital aerial photo was acquired during May 1995. The project area is located at Desloge, Missouri and it is characterized by variation of terrain patterns from the very steep slopes along the river banks to rolling and flat areas. The digital frame camera was installed on board the Photo Science, Inc. Piper Navajo Chieftain plane. Four flight lines and a supplementary line were flown at about a 6500 foot flying height which resulted in a slight increase in endlap and sidelap coverage. The data was then processed at the ground facility of Daedalus Enterprise, Inc. at Ann Arbor, MI, where about 100 black and white digital images were obtained in a TIFF format ready for the softcopy workstation processing. A few days prior to the flying, the ground surveying crew established an accurate network of nine control points using GPS techniques and the already established NGS points. Each ground control point was marked with an aerial photography target in the shape of two crossed panels one and a half feet in width and six feet in length.

2.4 Digital Photo Triangulation

A total of 24 frames that covered the testing site and a total of eight paneled ground control points were used to form the block of photos that is later oriented and triangulated on the Autometric-Vision International softplotter. Considering all the problems that are inherent in the interior parameters of the DFC, the stability of the triangulated block was of concern. Therefore, a smaller block of seven frames with a suitable number of ground controls was used for the purpose of this analysis.

The interior orientation was achieved by measuring the pixel of the four corners and the image coordinates system origin was assumed to be at the point of intersection of the two axial lines connecting the opposite corners. Although this assumption is not free from error, it was necessary as no accurate information was available about the principal point location.

2.5 Image matching autocorrelation, and surface modeling

The triangulated pairs were then correlated and a digital elevation model was generated using the available tools of the softplotter. The generated surface was then modeled using both the terra model and the Intergraph MGE Modeler. A set of two foot contours was generated. Figure 1 shows a clip from the generated contours.

3. RESULTS AND DISCUSSION

In examining the pixel resolution on the softcopy station, the 0.7 m pixel ground coverage seems to be adequate for revealing ground details. The ground targets were easily distinguishable. Due to an appreciable amount of error propagation in the larger block which resulted from camera interior instability, number and distribution of control points (as some of the control points disappeared prior to flying due to local land use activity), a smaller block of seven digital photographs was triangulated and autocorrelated to produce the digital elevation model (DEM). Examining the obtained DEM and the derived contours reveals a great agreement with the set of contours derived conventionally from a photogrammetric stereoplotter. However, it is found that there is a bias in the digital surface generated from softcopy which is clearly reflected in Table 1. The table shows the data from twenty points selected on a variety of terrain patterns that were measured stereoscopically from the three-dimensional digital stereopair displayed in the softplotter and the same locations were selected and measured in the surface generated by conventional photogrammetry. It is noticed that discrepancy is reduced in magnitude as the evaluated point is closer to a control point. Some other points deviated from the root mean squares of error or bias and that is believed to be either because of the changes in the ground surface as there were a few years between the two mapping dates, or it is because of some trees or brush covering the ground surface.

It is also noticed that the discrepancy pattern changes considerably at the step slope at the river banks as the correlation technique faces more ambiguities due to slope relief and dense tree coverage.

4. CONCLUSIONS

The study has shown that an alternative for the conventional film frame camera and the analogue film/diapositive dependent photogrammetric operations is closer to reality, and only minor developments are needed before the fully digital photogrammetric technique becomes the production tool of the near future.

The study also concluded that in order for available commercial digital frame cameras to take a serious step toward recognition as a mapping metric camera, the following points must be resolved:

i. Camera calibration is essential, whereby all interior parameters of the camera are determined accurately.

ii. Although an array of 2000x2000 pixels can be proved useful for some applications, a larger array (preferably 4000x4000 or larger) and a lens with a wider field of view is essential to match the conventional frame camera.

iii. Self calibration option in the digital aerial triangulation packages for the soft plotters that are used to process the digital camera production is strongly recommended to enhance the final output of the digital mapping process.

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Table 1. Comparison of the digital camera and conventional DEM

Point #	Easting (ft)	Northing (ft)	Elevation from digital camera (ft)	Elevation from old map (ft)	Discrepancy (ft)
1	46184.0	31883.0	804.0	783.0	21.0
2	46465.0	31705.0	775.6	764.0	11.0
3	46093.0	32639.0	722.0	723.0	-1.0
4	45369.0	30594.0	809.0	779.0	30.0
5	46081.0	31300.0	807.0	785.0	22.0
6	45562.0	31074.0	813.3	783.0	30.0
7	45213.2	30442.0	806.8	780.0	26.8
8	45692.0	29670.0	782.6	775.5	7.1
9	46365.0	30351.0	718.5	694.0	24.5
10	45719.0	29018.0	755.3	777.0	21.7
11	45212.0	29768.0	783.26	783.0	0.26
12	45383.0	32738.0	767.0	750.0	17.0
13	45923.8	32882.0	727.0	726.0	1.0
14	44817.0	33432.0	726.0	725.8	0.2
15	43458.0	32575.0	748.0	740.0	8.0
16	43224.0	31560.0	749.0	722.5	26.5
17	43917.0	32424.0	784.0	766.0	18.0
18	44144.0	31895.0	799.5	782.5	17.0
19	44868.0	31896.0	804.0	787.0	17.0
20	45185.0	32545.0	795.0	775.0	20.0
Average Residual(ft)					12.9
RMSE(ft)					19.3

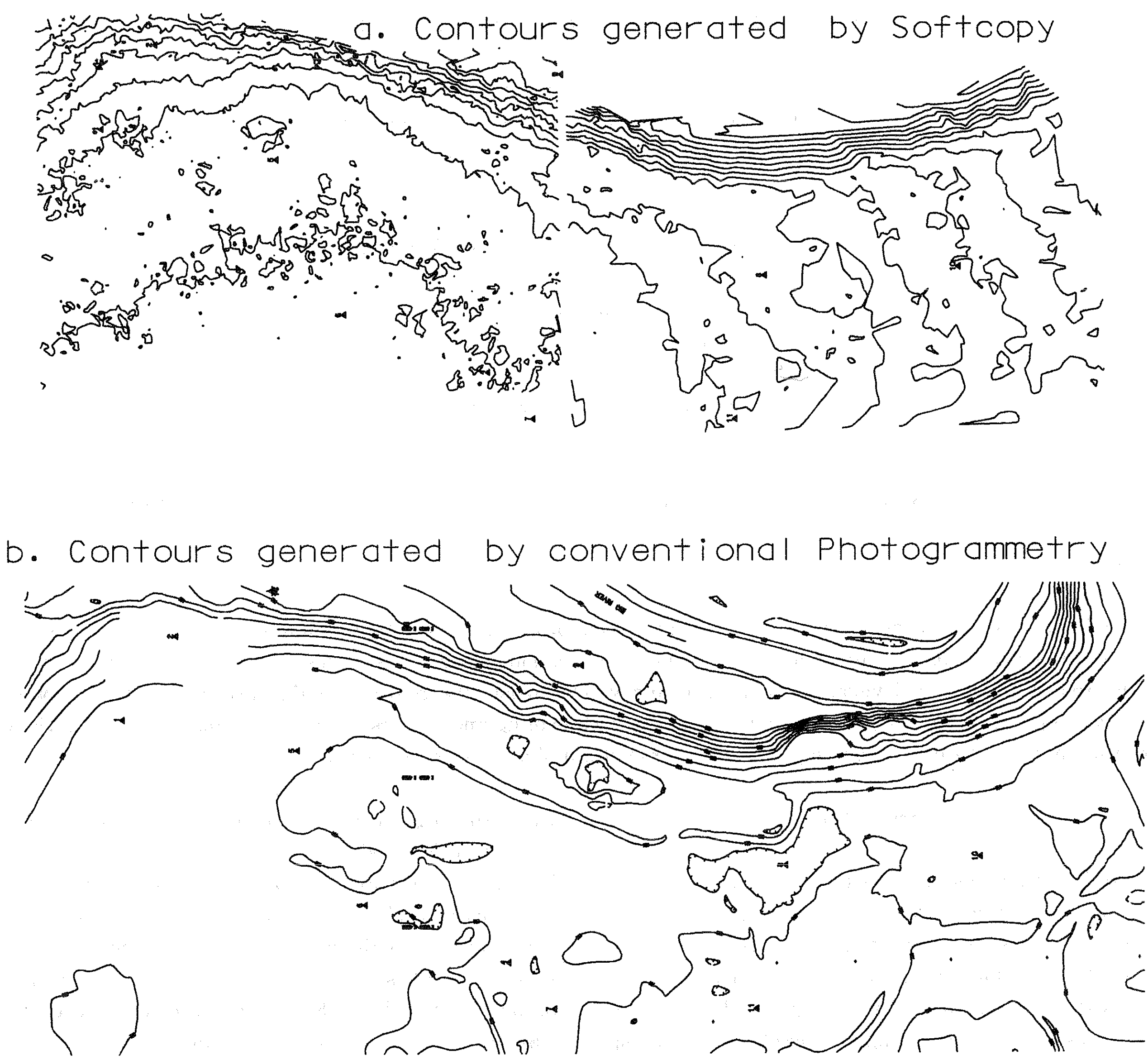

Figure 1. Contours generated from the two approaches