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APPLICATIONS AND TESTING RESULTS OF THE OPTICAL POWER SPECTRUM --ETC(U)
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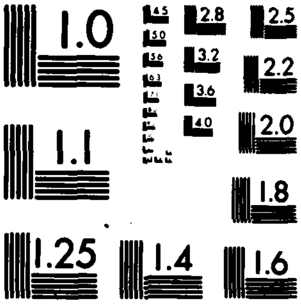

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A Coherent Optical Subsystem (COSS) for scanning photographic imagery is interfaced to a minicomputer forming an Optical Power Spectrum Analyzer (OPSA) designed for applications of feature classification and "image quality" measures on a production basis. Applications are directed at finding non-correlation areas of aerial imagery intended for use in automated photo-grammetric information and the overall utility of the image.

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APPLICATIONS AND TESTING RESULTS OF THE OPTICAL POWER SPECTRUM ANALYZER

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ABSTRACT

A Coherent Optical Subsystem (COSS) for scanning photographic imagery is interfaced to a minicomputer forming an Optical Power Spectrum Analyzer (OPSA) designed for applications of feature classification and "image quality" measures on a production basis. Applications are directed at finding non-correlation areas of aerial imagery intended for use in automated photogrammetric compilation equipment. The image quality functions are concerned with photogrammetric information and the overall utility of the image.

INTRODUCTION

The OPSA was designed after a considerable research effort on the Recording Optical Spectrum Analyzer (ROSA) had established that optical/digital processing would be a beneficial means of rapidly screening aerial photography (Ref.1). Inherent in this task was the work of many others who laid the ground work, tested pattern classification algorithms, and applied power spectrum analysis in a variety of applications (Ref. 2, 3, 4, 5).

Data acquisition/processing, system hardware design, and power spectrum optical design have all evolved since the initial efforts of Lendaris and Stanley (Ref. 5). Beam filtering masks have been replaced by a polar symmetric ring-wedge detector which offers a tremendous advantage in data acquisition time. Two dimensional positioning of the image with respect to the input beam aperture has always been a trade-off between accuracy of the hardware and time. Manual positioning was slow, x-y positioning stages along with their computer compatability became the next generation. Inherent to the stages were their time limiting stabilization characteristics and their inability to keep up with the ever increasing capabilities of the digital computer.

Telecentric optical scanning systems represent the latest technology and are a true challenge to the system architecture of any present day computer. While telecentric systems offer the speed, its stringent design parameters must include optical stability, state-of-the-art optics, thermal and laser stability consideration. Once the optical design has been optimized, the designer must then confront the digital electronic design of the scanner and its interface to the computer. System applications, scanning methodology, data accuracy requirements, and computer-controlled functions must all be established to meet the needs of the end user. Most important is optimization of the electronics and its direct relation to the optical subsystem and the computer.

Real-time data processing requires nanosecond timing, and places strict requirements on system architecture, operating system overhead, special interrupt handling with associated high-speed drivers, and microprogrammed instruction subfunctions. Requirements insist on a thorough knowledge and optimization of design parameters for successful integration of the above topics into a production oriented optical power spectrum analyzer. The OPSA design has integrated a number of state-of-the-art technologies and represents the culminated efforts of a group of diversified professionals.

Present work on the OPSA has emphasized software design for both testing and production applications. Directly associated with this software are the high-speed software driver requirements for real-time classification processing. This paper will therefore address hardware functions of the OPSA and software parameters, with a brief overview of some preliminary results.

APPLICATIONS

Due to the importance of aerial photography to mapping and associated stereo compilation equipment, it was evident that a screening device would provide information on the utility of the image. Correlation of a ground point in a stereo pair of images relies on digitally overlaying the points via a best fit of a set of points, where the set of points includes the desired ground point (Ref. 7). Non-correlation results in errors and the requirement to find another set of imagery to cover the non-correlating area. Present screening is done manually to enclose possible adverse (non-correlating) areas and in a separate step to find the percentage of cloud cover of an image.

Requirements for adverse areas are concerned with identifying areas of non-correlation on stereo compilation equipment, which implies homogeneity of the area or a density outside the range of the equipment. Spectral information (radial frequency, angular orientation) lends itself directly to identifying homogenous areas, and absolute density calibration of the OPSA allows density measurements to be analyzed. Energy (intensity) distribution of the Fourier diffraction pattern itself implies texture (feature) characteristics, with homogenous areas implying little scattering. This is a simplistic approach to the problem, but serves as a starting point. Thus, there is a tremendous advantage to analysis of optical diffraction patterns (optical processing) verses texture analysis of a set of pixel data values generated by a standard optical imaging system.

The preliminary adverse area feature set consists of clouds. Other feature sets will consist of water, "dense" forests, snow and sand. Image quality parameters consist of density calibration of the OPSA, histograms, density range, contrast measurements, and film duplication transfer functions.

HARDWARE

The COSS is a computer-controlled roll film scanning subsystem which images a Fourier diffraction pattern on a 64-element ring-wedge detector. It consists of three major elements: (a) a telecentric scanner illumination system, (b) the Fourier transform optics, and (c) the precision continuous film transport. There are six aperture sizes from 1mm to 10mm, with any combination of 1mm to 10mm for across and along film sample spacing. This allows optimization of scan time per frame and allows matching resolution requirements to meet specific applications.

Very small beam positioning errors are compensated for with a pair of piezolectric drivers which are driven via error signals from a quadrant cell, which detects optical alignment errors. A galvanometer provides a linear scan across the film plane and is controlled via a digitally synthesized input for sampling strategy. The wave form for the galvanometer is stored on programmable read-only memory forming an analog ramp which establishes the scan frequency.

Synchronization of the data sample with the scanning laser beam at the film plane is accomplished with an optical clock. A grating is scanned via the deflection of a second laser beam off the galvanometer. The grating interrupts the second laser beam at a rate corresponding to 1mm increments at the film plane. This interrupted beam is focused on a photo cell whose output is connected to logic circuitry thus establishing synchronization for data input to the computer.

The desired aperture is selected via a turret assembly of 6 objective lenses in combination with 6 beam masks. This assembly gives a diffraction limited spot of light with a center-to-edge intensity fall off less than 50 percent at the film plane.

A 64-element ring-wedge detector is connected to a High-Speed Diffraction Pattern Sampler (HSDPS) with each element having its own associated amplifier and analog storage circuitry in the HSDPS. An analog-to-digital converter sequentially addresses and converts the analog signal every 40 microseconds. The digital output represents the intensity of the element in a range of about 32K. This digital output is interfaced to a minicomputer.

An attenuation wheel of 8 neutral density filters (0.0 to 1.0) is incorporated to prevent saturation of the ring-wedge detector. Density calibration of the COSS is attained by selecting each of the 8 density filters and correlating the intensity at the detector with that filter's known density. Access to the attenuated beams' intensity is also monitored by a photo cell placed near the film plane. Another photo cell monitors the beam before the attenuation wheel, thus any laser intensity drift during the calibration procedure, or during the scanning mode, can be corrected.

SOFTWARE

A matrix eigenvector software routine is used as a means of establishing the merit of the statistics used in feature classification decisions. This routine is an adaptation of a method published in a paper by R. L. Mattson and J. E. Dammann (Ref. 8). It consists of a technique to approximate the eigenvector corresponding to the largest eigenvalue of a matrix. This maximized eigenvalue matrix represents the weighting function (relative merit) of the statistics to be used in the classification algorithm. Thus the relative merits of a group of statistics can be used as a means of establishing the most useful statistics.

An x-y digitizer is used as a means of establishing the "ground truth" of a particular feature type. The digitized x-y coordinates consist of a set of contiguous values representing the circumference of a feature which are passed through either a three or six dimensional warping function. (Ref. 9,10). The input for the warping function consists of a set of known sample points identified from the scanned data base, thus there is correlation (1 to 1 mapping) of the scanned data base with the x-y digitizer data base. The correlated coordinates are then used as input to a software routine that finds all points within the circumference enclosed. The software is flexible enough to allow input of a set of circumferences or lines (non-enclosed). This "ground truth" is then compared (overlayed) to the output of a feature classification algorithm used on an OPSA scanned data base. Thus, the percentag overlay of the two data bases gives a relative accuracy of the decision algorithm.

The x-y digitizer is also used as a means of inputing D-log E curves for generating transfer functions used for duplication. The transfer function is generated from the D-log E curve of the original image and the D-log E curve of the proposed duplicating film. It is assumed that some of the image "characteristics" (density range, contrast, histogram) of an original image can be representative of the image. By passing the OPSA image data through the transfer function, the "characteristics" of the duplicated image can be made, thus determining if the duplicate meets its specific requirements. In a similar manner, if the desired "characteristics" are known then all D-log E curves in the data library can be searched to find a best fit, giving the duplicate film type and processing requirements.

Computer control of the COSS allows the setting of the along and across film sample spacing, galvanometer position, computer or manual mode, film width, and slew direction and speed. The frame counter, film length counter, laser power, optical clock status can all be monitored via the three software drivers that control the OPSA.

RESULTS

Classification results are based on relating the x-y digitizer ground truth to the decision classification algorithm results for cloud features. This allows a total percentage comparison and a point by point assessment of the accuracy of screening for clouds. A two-dimensional feature vector consisting of a threshold of the D.C. intensity and a ratio of a sum of low-frequency spectral rings to higher-frequency spectral rings were used for classification. Selection of the threshold and sum of ring elements was determined by examining ring combination ratios and using the combination with the greatest relative separation. Tests were run under varying conditions for 2, 4, and 6 mm apertures of a test image. Preliminary results indicate better than 90 percent accuracy.

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