CANADIAN
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COLLOQUIUM V

PETROLEUM SURVEYING IN THE 90'S ENVIRONMENT

October 4 - 6, 1989
CALGARY CONVENTIONCENTRE
CALGARY, ALBERTA , CANADA

Co-Sponsored by
Canadian Petroleum Association
Canadian Institute of Surveying and Mapping
Alberta Land Surveyors Association
Canadian Hydrographic Association (Prairie Schooner Branch)

THE IMPACT OF DIGITAL WORKSTATIONS ON TOPOGRAPHIC MAPPING APPLICATIONS OF REMOTELY SENSED DATA

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ABSTRACT

The convergence of several technological trends is enabling the development of digital workstations for topographic mapping applications. The development of these 'softcopy' workstations is being approached from the small scale (1:50,000-1:100,000), image processing direction on the one hand, and from the larger scale photogrammetric direction on the other. Powerful computational abilities, large storage, fast I/O, impressive image and graphical visualisation capability, stereo viewing and the lure of automated coordinate data extraction and processing are now available on a single workstation at a price that is very competitive with 'classical' instrumentation such as analytical plotters. In this paper we review these general trends as they apply both to digital and film input data and present an example of a system that is being applied to airborne SAR data for topographic mapping purposes. The general trend points toward the emergence in the future of an integrated, automated spatial information system.

INTRODUCTION

Over the past decade, the major processing activities applied to commercial Remote Sensing (RS) products have been driven by thematic information extraction needs. Image processing workstations have been developed and widely applied, particularly with respect to multi-spectral SPOT and Landsat data. More recently, the extraction of topographic information from SPOT imagery on the one hand , and from airborne Synthetic Aperture Radar (SAR) on the other, have been implemented commercially at scales of 1:50,000 to 1:100,000.

Approaches to date have not fully exploited the inherently digital form in which the data are presented to the user. Typically, photogrammetric techniques have been borrowed, digital data being processed into film in order to utilize existing instrumentation such as analytical plotters for extraction of coordinate point data. Other parts of this hybrid process would be done on general purpose computers and image processing systems.

In this paper we present arguments to show how the availability of more powerful 'soft copy' workstations should enable the replacement of the hybrid approach with fully integrated digital methodologies. The advantages should manifest themselves in greater performance as indexed by parameters such as 'throughput', accuracy, versatility and portability.

The arguments that support the use of soft copy workstations for geometric processing of RS data perhaps apply equally to photogrammetry using traditional film sources from aerial photography . Until cost effective digital cameras come into wider use in the future, it is likely that film will continue to be widely used for mapping at scales of 1:20,000 and larger.

In general , the development of softcopy workstations is being approached from two directions as will be discussed in this presentation. The relationship of scale to applicable mapping technology is itself the pre-cursor to these developmental streams and will be reviewed. To illustrate the trend, we provide a brief description of the SSCS, a softcopy workstation developed for extraction of topographic information from SAR imagery.

SCALE VS. MAPPING TECHNOLOGY

GENERALIZATION AND DIRECT SMALL SCALE MAPPING

The advent of satellite and airborne digital remote sensing imagery has complemented aerial photography as a source of mapping information. However, we need to understand that the use of classical aerial photography is the foundation of large scale mapping for engineering projects at scale 1:1,000 to 1:5,000 and for topographic map generation at scales 1:5,000 to 1:50,000. In traditional mapping terms one creates small scale map at scales 1:50,000 to 1:250,000 and smaller by generalization of larger scale maps.

This concept has been in use in industrialized societies, but has not been fully applicable to poorly mapped areas in less-developed regions of the world. There a willingness has been evident since the advent of satellite remote sensing and airborne radar imaging to develop a small scale mapping coverage directly from small scale imagery at scales 1:100,000 to 1:5,000,000. In those instances larger scale mapping supplements the initial small scale coverage, perhaps in areas of dense development and industrial activity.

Remote sensing image analysis has thus had its first inroads into topographic mapping at scales of 1:50,000 and smaller, but has not been a source for mapping data at scales larger than 1:50,000. This remains within the domain of aerial photography.

METHODS OF MAP PRODUCTION

The classical mapping process proceeds from aerial photography via geodetic point positioning to the collection of height and planimetric manuscript data in stereoscopic image pairs on a plotter. Via editing and drafting one develops the cartographic map separates ready for printing.

The state-of-the-art, *conventional* mapping process will still employ the same procedural elements, but will deal with extracted information strictly in a digital domain; all coordinates and associated descriptive data are processed digitally; the image is and remains on film.

Softcopy or pixel processing has not yet altered the procedures in a dramatic manner. Instead of film imagery that is viewed optically, a pixel array is presented to the human operator who views it optically,

However, since current digital imagery is at small scales, one commonly does not address the mapping issues of large scales but has been free to define new production procedures, unencumbered by cartographic and photogrammetric conventions. The most important element in this development is image rectification or geo-coding and the image map. A procedural element of some importance at small scales is the automated creation of Digital Elevation Models (DEMs). While one encounters great difficulty in automated stereo matching at large image scales, mostly due to vertical objects like man-made structures and vegetation on the "bald Earth" , one does not suffer from those factors at small scales.

The production chain for such small scale goals is therefore automated stereo-correlation, geo-coding/ortho-rectification, and presentation of an image map. The need to adjust a block of imagery has not been a significant requirement due to the large area covered by one image pair. If planimetric information is to be created, then this is conveniently done from geo-coded imagery in a monocular fashion.

Recent advances are now also providing for the softcopy analysis of film photography. This requires the scanning of photography to obtain a digital pixel array, and the subsequent use of the digitized photography in an interactive stereo workstation environment. This replaces the analytical plotter by the digital workstation, but does not yet alter the fundamental mapping procedure from photography, nor the mapping product consisting of map separates or digital file for supply to a Geographic Information System (GIS).

These recent advances provide the unification of mapping procedures so that no significant differences in technology should exist as a result of scale. Further progress should result in a combined map-image data format in which images and map data *interact* for automated updating and smart visualization of the data for rapid and most effective use by a user. The historical trend, we believe, is summarized in table 1.

	Large Scale Mapping	**Small Scale Mapping**
Traditional	Aerial photography → DEM, Map separates	Map generalization → Map separates
State-Of-The-Art, Conventional	Aerial photography → DEM, GIS	Remote Sensing → DEM, image mapping
On the Verge of Acceptance	Scanned aerial photography, digital source material → DEM, GIS	
Future	Integrated, automated image-based spatial information system	

TABLE 1: Scale and Mapping Procedures

FROM ANALYTICAL TO DIGITAL PHOTOGRAMMETRIC SYSTEMS

The transition from the invention of the computer-controlled analytical plotter (Helava, 1958) to its full introduction took about 20 years, to the mid-1970's. Acceptance was driven by a combination of

- manageable mini-computers to replace bulky special computers;
- acceptance of the precision block adjustment with the associated saving in ground control point measurements;
- increasing market for digital map data and the gain in productivity when creating such data.

Digital image processing has its developmental roots in the space program and began with the lunar and martian surface imagery in 1964, as well as the aircraft multispectral imaging in 1966. Softcopy photogrammetry systems are now beginning to be competitive in price and performance to analytical systems, and are expected to far surpass them due to

- reduction in hardware costs for graphics workstations;
- emergence and portability of stereo photogrammetric software;
- increased acceptance of GIS and thus of GIS-image superposition and GIS-editing;
- accomplishment of throughput advantages over analytical plotters through the ease of quality control, through avoidance of inertia due to mass of mechanical parts, and through automation.

However, digital photogrammetric workstations have not arrived yet. What has arrived are remote sensing image analysis systems, and components for photogrammetric systems. The configuration of end-to-end solutions remains largely open.

The use of digital source material is restricted at this time to very few and specific users such as satellite imagery from SPOT and Landsat, from airborne SAR, and from pending satellites to be launched (e.g., E-ERS-1, J-ERS-1, Radarsat). Typically these are data which support small scale mapping.

GENERAL APPROACHES TO SOFTCOPY SOLUTIONS

A recent survey by the authors indicated about 15 North American vendor offerings of proposed softcopy mapping solutions of varying functionality, cost and degree of completeness. There are two fundamental development streams, the first arising as enhancements to image analysis systems (functionality emphasizing small scale mapping applications), the second being an extension of analytical photogrammetry into the digital domain (highlighting large scale vector data capture). Systems arising from the former stream embody functionality which facilitates the interpretation of the image and the integration of data sets. Systems which are a product of the photogrammetric stream stress functionality related to vector data capture and update. The image is interpreted and the resultant data routed to a GIS for spatial analysis query.

The two development streams are also characterized by how they handle elevation data and this leads to differing strategies for image display. Systems based on image analysis systems tend to be monoscopic and are sometimes limited to geometric rectification based on polynomial transforms. The photogrammetric systems are usually based on stereo viewing. Hybrid systems are now arising which are based on monoscopic representation of orthographically corrected imagery. Stereocorrelation is playing an increasingly important role in the orthographic correction process. Stereocorrelation routines, while having their roots in photogrammetry, were first widely implemented for applications employing stereo SPOT imagery. The routines are currently migrating to mapping applications employing scanned aerial photography. This migration is being effected with varying degrees of success.

While the development streams are clearly convergent they still embody differing display philosophies. The photogrammetric approach began with binocular viewing of two video displays and has moved toward binocular viewing of a single display and single polarized liquid crystal shutter displays. Image analysis systems have evolved along one of two lines: high end systems have tended to utilize orthographically corrected imagery; lower end systems have tended to adopt approaches using anaglyphic rendering.

The impetus for both these development streams has been to broaden the user base by placing accurate and sophisticated mapping tools in hands of more people and organizations. The move from analytical plotters is a function of both cost and functionality. The softcopy workstations facilitate the use of stable imagery and an analytical measurement system without precision optical trains. Set up and manipulation of the imagery is greatly facilitated relative to conventional analog and analytical plotters. The systems are fast, easy to use, and may be readily integrated with GIS software. Furthermore, they facilitate data base revision through image and vector superimposition. The systems are also suited to semi-automated feature extraction and classification which was not the case for technologies directly employing emulsion-based imagery.

Aerial triangulation and numerical adjustment functionality has not yet been successfully implemented on softcopy mapping systems owing to resolution limitations inherent in the scanning systems which are currently available on the commercial market. This is the last phase of the traditional mapping process to be implemented in the digital domain.

A by-product of this fusion of image analysis, photogrammetry and GIS in the softcopy domain is the advent of the digital orthophoto as a stand-alone data product. This product, in conjunction with existing GIS tools, has the potential to revolutionize the way we compile and utilize geographic data. From this transformation it is a relatively modest step to the use of digitally acquired imagery in a truly integrated image-based spatial information system.

FILM SCANNING

End-to-end softcopy workstations for large scale mapping need to include the conversion of film into pixel arrays, and thus are dependent in their acceptance on the successful integration of a film scanner into the analysis system. Since the majority of all mapping is at large scales one needs to expect that full acceptance of digital workstations only follows the successful integration of end-to-end softcopy production systems that demonstrate overall superiority to the current analytical systems of large scales.

One may argue that a film scanner needs to:

- be geometrically accurate;
- reproduce the film information fully;
- be reasonably fast.

Geometric accuracy will need to support photogrammetric standards to permit one to achieve coordinate measurements with errors of $\pm$ 2 microns, or a fraction of a pixel, dependent on the process. "Full information" requires that no radiometric or geometric resolution be sacrificed. This is the case if mapping photography is scanned at pixel sizes of 10 microns, if one assumes a film resolution of 36 line pairs per millimeter, or even with smaller pixels if resolution were to exceed this value. Radiometrically there exists a trade-off between geometric resolution and bits per pixel (Hempenius, S.A., X. Jia-bin 1986). However, one can generally expect that densities need to be resolved in a range of 0.2 to 2.4.

High-end scanning systems approach the needs of the photogrammetric scanning function, whereas most other scanners do not. One must relax the requirements in geometric resolution and accuracy significantly to be able to successfully use lower-end scanners. Such reduced requirements may apply to the use of photography for the creation of ortho photographs, and as a "backdrop" in conjunction with a GIS. They do not apply to the use of photography in an end-to-end photogrammetric system for precision mapping to common national standards.

THE STARMAP SOFTCOPY SYSTEM (SSCS)

STARMAP is the name of a process developed for the production of topographic mapping information from STAR-1 radar imagery (Mercer et al, 1989). The products include DEM's and rectified ortho-images mosaiced into radar image maps at scales of 1:50,000 or 1:100,000. The process has been implemented on a hybrid configuration including an analytical plotter for stereo coordinate extraction from film and separate computing facilities for DEM processing and the various radargrammetric steps. There are several disadvantages to this implementation which motivated the development of its replacement by a single softcopy workstation. The SSCS, (Leberl et al, 1991) is in its final development stages at the time of submission of this paper, and demonstrates the following features:

- It is hosted on a super-mini computer which supports stereo viewing on a single terminal, provides strong visualization capability, and has the power to perform computationally intensive tasks rapidly. Disk, RAM and bus speeds and capacities are adequate to store, transfer and manipulate multiple large (typically 50MB) image strips in near real time fashion.
- Operations that are performed on an analytical plotter (e.g., pan, zoom, brightness/contrast adjust, etc), can similarly be performed on the SSCS with similar speed.
- Coordinate point extraction (grid points, breaklines, tie points,etc) is facilitated through optional display of the points in stereo as they are acquired, thus reducing errors .
- Stereo editing of contours is supported.
- Interactive auto-correlation is supported.
- Topgraphic nuance which is revealed in the imagery by grey-scale subtleties is incorporated into the DEM through a shape-from-shading technique.

These features are expected to improve both throughput, accuracy and cost performance by comparison with the hybrid process it replaces.

CONCLUSION

The convergence of several factors including availability of increasingly powerful, cost effective digital work stations, digital mapping solutions at small scale from SPOT and SAR, and functionally adequate, cost effective film scanners for medium scale film input, are enabling the emergence of softcopy stereo systems which support creation of DEM's, geocoded ortho-images, planimetric information extraction and GIS integration. While functionality is still missing one might expect to see the emergence, within a few years, of a fully automated, integrated, spatial information system in a single workstation.

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