PHOTOGRAMMMETRIC PROCESSES AND SYSTEMS
A Review of Developments and Trends

Z. Jaksic
Photogrammetric Research
National Research Council of Canada
Ottawa, Ontario, Canada K1A 0R6
Commission II

ABSTRACT

Scientific and technological advances in photogrammetry are best reflected in the development of instruments and systems for processing and analysis of photogrammetric data. This paper addresses the major areas of intensive research and development activity related to the analytical instruments, the automation of processes, the photogrammetric systems for land information data bases, the photogrammetric digital image processing systems, and the instrumentation for digital, real-time photogrammetry of dynamic processes. The technological background and motivations for innovation in these areas are reviewed and the general development trends are outlined.

INTRODUCTORY REMARKS

The evolution of a discipline depends on its capacity to diversify its activities and its ability to respond to new requirements. The main factors influencing the course of evolution are the basic innovations which open new areas of activities and the improvement innovations which support further progress in the established areas of activity. Lack of innovations leads to stagnation and eventual extinction of a discipline.

Photogrammetry is in essence an information gathering and processing discipline based on image metrology and interpretation. Its techniques are to a great extent dependent on the available instruments and systems. Often the development of a new instrument actually inspires the development of a new technique. Consequently the technological advances in photogrammetry are not only reflected in, but also motivated by the innovations in the instrument design. The development of the instrumentation for analysis and processing of photogrammetric data has closely followed the developments in the general field of digital information processing. In fact, the digital methods for the processing of information have become the major tool of contemporary photogrammetry and the major factor influencing the formulation of new concepts, the establishment of new techniques and the design of new instruments and systems.

Off-line analytical photogrammetry was the first branch of photogrammetry founded on the concept of digital processing of data. This has been undoubtedly one of the significant steps in the evolution of photogrammetry that can be qualified as a basic innovation. The attempts to expand the digital techniques into the areas of activities requiring on-line processing of information have led to the invention of the analytical plotter which is another basic innovation that opened new areas of activities and was instrumental to the generation of many improvement innovations such as the on-line aerial triangulation and on-line digital image correlation techniques for automation of processes.

The areas in which the most active research and development work related to the instrumentation for processing and analysis of photogrammetric data is expected to concentrate in the foreseeable future are:

- Analytical instruments
- Automation of processes
- Photogrammetric systems for establishment and maintenance of cadastral, cartographic and other land information data bases.
- Photogrammetric digital systems for measuring, processing and analysis of digital imagery.
- Instrumentation for true real-time digital photogrammetry and machine-vision.

ANALYTICAL INSTRUMENTS

Since the concept underlying the basic innovation leading to the design of analytical plotters is the incorporation of digital computing devices into the operator-image-operator feedback loop, these instruments may be defined as finite state digital machines for real-time addressing of photographs as two-dimensional arrays. Consequently an instrument with two photo-stages has four degrees of freedom, defined by four addresses represented by four photo-stage coordinates. Hence, the measuring of photo-coordinates is a function equivalent to addressing. This function is needed whenever an observation or a measurement is required, that is, in all cases involving the on-line, real-time operation of the system. Therefore the potentials and the limitations of analytical instruments are determined primarily by the structural characteristics of the image addressing components and interfaces.

The implementation of a particular process on an analytical instrument requires the organization of proper sequences of logically complete elementary functions. These sequences consist of a combination of numerical operations performed by the computer and dynamic processes related to addressing performed by the positioning devices. Therefore the elementary functions are of two distinct types, that is, the functions concerning the transformation of some input data into some output data or return data, and the functions concerning the actions of system's physical devices (e.g. electro-mechanical devices). The latter are involved in all real-time operations while the former are "pure" computations that are in general time-independent and may be for all practical purposes regarded as off-line computations. Consequently very few instructions (i.e. macro-routines) need be added to the repertory of the programming language in order to perform any real-time process in any application of the analytical instrument. If the interfaces and the addressing devices are properly designed, only six additional instructions will allow for any possible action of the physical devices in comparator or plotter mode of the instrument (Jaksic, 1980). The proper interpretation and further analysis of the logical foundations of these design characteristics is essential for the optimal design and evolution of future analytical instruments.

A number of improvements in the design of analytical instruments are under way. Considering the cumbersome construction of positioning and measuring components based on electro-mechanical devices and moving assemblies, and the accompanying delays in their responses requiring complex controls, it is obvious that a departure from their present design principles is eminently necessary. A step in that direction is the superposition comparator design principle (Pekelsky, 1982). Also, the optical image transfer components of analytical instruments offer little flexibility for the manipulation of transferred images. The use of electronic image transfer devices allow not only for a wide range of possible transformations of transfered images but also for their enhancement (Real, 1982). Electronic image transfer also eliminates the rigid constraints imposed by the optical trains on the overall design of analytical instruments, and allows for a flexible configuration of system components (e.g. the photo-stage configuration) and for easier implementation of techniques for real-time superposition of graphics in the stereo-model.

The overall organization of software packages and the optimal design of application programs exploiting the best features of man-machine interaction are still wide open fields for research and development (Slama, 1982). Some unique, already developed, on-line techniques for compilation of time-dependent imagery, for exploitation of multi-model solutions in close-range photogrammetry and for processing of multi-media photography are good indicators of the potential of analytical instruments for opening up new areas of application.

AUTOMATION OF PROCESSES

Some of the routines and techniques of on-line analytical photogrammetry which do not require the operator's intervention, such as the routine for automatic positioning of the measuring mark in predetermined positions or the editing playback technique, may be considered as automation of processes. On closer examination, it is evident that these simple automatic processes are just a consequence of a direct computer drive of positioning devices without the involvement of any decision making control processes or machine-intelligence.

Taking in account the present status of the theory and technology in artificial intelligence a full automation of all the processes needed to, for example, extract from images all the required information for the establishment of digital files of a cartographic data base must be deemed intractable. For instance the pattern interpretation that is an integral part of all the processes for feature compilation is still confined within the boundaries of human intelligence. This is the reason that the only practical way to deal with planimetric features is to generate an orthophoto, that is, to perform a pictorial-to-pictorial conversion by automatically transforming the metric information and leaving the semantic information virtually unchanged.

The level of machine-intelligence needed for the extraction of information on elevation is somewhat lower since it can be based on relatively simple automatic image matching techniques. Attempts at automatic generation of digital terrain models and digitizing of contours have been made by analog electronic scanner correlators and by optical scanners using digital correlation techniques. The goal of these devices is the measurement of parallaxes in an oriented model and the consequent determination of elevation or generation of a control signal for the positioning of stages. The image matching in these devices has been based by and large on cross correlation of two image density functions (Konecny and Pape, 1981). The cross correlation function has a maximum when the images are shifted the correct amount relative to one another.

These devices have proven quite successful under favorable conditions. But they fail in cases of discontinuities (e.g. large scale images of built-up areas), on steep slopes, and where a correlation is possible simultaneously at different elevations (e.g. sparsely forested areas). These difficulties may be overcome with the aid of the human operator, but the processes have to be slowed down to the speed of human responses. If the outputs are generated at high speeds without human intervention the indicated conditions will result in extensive and costly post-editing. In both cases the economical gains are diminished. It is evident that even in the less demanding case of automation of elevation collection some additional image matching techniques based on criteria other than correlation of image density functions such as edge detection and symbolic matching that exploit qualitative aspects of images and consequently are less dependent on gray level differences, have to be investigated and implemented in order to achieve a reliable full automation (Horn, 1983, Baker and Binford, 1982).

For full automation, besides the on-line techniques, the off-line techniques could be considered. For partial automation of processes where the human operator monitors and aids the image matching devices or where the image matching device supports the actions of the human operator by performing some selected tasks on request (e.g. parallax measurements in orientation procedures) only the on-line techniques are implied.

In more demanding cases of automation of processes where the meaning of patterns has to be understood and defined in a particular context, the development of techniques require more research closely related to the development in the disciplines concerned with image understanding and artificial intelligence. Evidently the full automation of photogrammetric processes represents an area whose further development would require the commitment of considerable resources.

SYSTEMS FOR LAND INFORMATION DATA BASES

In the areas traditionally served by photogrammetry the implementation of the data base concept in cartographic, cadastral and other land-related systems has significantly influenced the concepts about the objectives, the procedures and the configuration of photogrammetric systems for collection of information.

The primary function of these photogrammetric systems is the conversion of the source information registered on images into a desired, well-structured form which may be numerical, pictorial or graphical. Formally all the procedures for the achievement of a particular objective may be looked upon as a combination of elementary processes represented by a certain conversion of information. All possible elementary processes or information conversions are indicated in the following matrix:

$$\begin{matrix} P\to P & P\to N & P\to G \\ N\to P & N\to N & N\to G \\ G\to P & G\to N & G\to G \end{matrix}$$

where P stands for the pictorial form of information storage or presentation, N for the numerical or digital form and G for the graphical form.

Numerical output is the principal form for geocoded information systems represented by digital files stored on direct access memory devices. The graphical and pictorial output forms may be regarded as supporting forms for information storage and presentation, which may be needed either as final supplementary documents or as intermediate output forms required in the process of information conversion (Jaksic, 1981).

The choice of components for composition of an information collection system includes a wide range of instruments: classical analog instruments, stereocompilers, analytical plotters, digitally controlled orthophoto and stereo-orthophoto generators; equipment for automation of processes, and an assortment of computing devices and interactive display and editing facilities. It is evident that, from these components, a number of differently configured systems may be built for the achievement of the same objective. In principle the choice of processes and the choice of instruments for the performance of these processes will depend mainly on the constraints imposed by criteria such as the required accuracy and speed, and by factors related to the economical constraints and the constraints imposed by human resources. In principle, there are two extreme approaches in the structural composition of the components. One is based on fully decentralized processes where the components are not physically connected and there is no possibility for a direct flow of information between the components. The other extreme is the fully centralised approach where the components are physically connected and the transfer of intermediate information between components is an internal transaction. Between these two fully off-line and fully on-line structures of the system, there is a number of possible configurations of compònents and sub-systems. Only one of these will be optimal for a particular set of constraints.

In practice the macro structure of the system will normally comprise two subsystems: the control densification subsystem and the subsystem for compilation of detailed information. The latter subsystem may be further subdivided into two parts: one for the collection of information on elevation and the other for the collection of information on features (i.e. planimetry).

A significant influence on the configuration of the information collection system will also be the form chosen for the source information record. At present, due to the requirements for reliable information of high metric quality, the only acceptable input for the control densification subsystem is the original analog photographic record acquired by precise, well-controlled photogrammetric frame cameras from airborne platforms. For the compilation subsystem, besides the original photograph, its derivatives: the orthophotos and stereo-orthophotos may be considered.

The most efficient control densification subsystem is the one based on analytical plotters with a special software package for on-line, analytical aerial triangulation. If this subsystem is on-line with the main computing and external storage facilities of the land information system the collected information can be fed directly into these. After the execution of block adjustments, the adjusted coordinates of control points and the orientation parameters can be stored in "control files" accessible to the analytical instruments of the compilation subsystems (i.e. to analytical plotters or analytical scanner-printers for generation of digital terrain models, orthophotos and stereo-orthophotos) for restoration of models without the repetition of exterior orientation processes (Kratky, 1982). The alternative to an analytical plotter based control densification subsystem would be a comparator-based subsystem. This subsystem may also be in an on-line configuration with the computing and storage facilities of the land information system but the advantages of this configuration are negligible. It should be noted that the analytical plotter based subsystem for control densification may be readily converted into a compilation subsystem for collection of detailed information (by the application software). This cannot be done with a comparator-based subsystem for control densification.

The most universal, on-line subsystem for compilation of detailed information directly from aerial photographs is the one configured around the versatile and accurate analytical plotters. The part of the subsytem concerned with the compilation of information on elevation could exploit specialized automated analytical plotters with high speed scanner-correlators for generation of digital terrain models. The collected data could be fed directly into the external storage devices of the land information system via an interactive editing facility. The feedback from the editing facility for digital terrain models allows the addressing of areas where the corrections should take place, directly in the model space. In general, during the performance of correction routines, the analytical plotters of the subsystems are under human control. For correction of some errors, such as the eventual gaps in the automatically recorded digital terrain models that can be discovered only after the completion of compilation from a number of stereo-models, the models in question can be readily reconstructed from data in the "control files". If required, the contours are normally derived from the digital terrain models by an independent, off-line, numerical-to-numerical conversion.

The part of the analytical plotter based subsystem concerned with the information on features operates under human control since the requirements for interpretations and decisions in the course of feature compilation is too complex for a technologically and economically viable automated control of processes. Considering the ease with which the analytical plotters and interactive editing facilities can be interfaced and the potential for the enhancement of the editing routines by the use of editing techniques available on analytical plotters, this type of feature compilation subsystem offers the best editing capabilities among all the possible configurations. Expanded by an automatic facility for numerical-to-graphical conversion, this type of subsystem also allows for an efficient exploitation of data in the data base of the land information system, for generation of various line-drawn graphical outputs such as cadastral, topographical, soil and land use maps.

An alternative configuration of the subsystem for compilation of detailed information from aerial photographs is the one based on hybrid instruments with analog plotters as elementary components. This type of subsystem, although viable, is, in general, less universal and less flexible. The decrease in compatibility between the hybrid and the digital system components is mostly felt in the areas of orientation procedures, interface with editing facilities, reconstruction of models, feedback of information into the original records and automation of processes.

If the accuracy of stereo-orthophotos fulfills the requirements of a land information system, then, the subsystem for compilation of detailed information may be composed of stereocompilers and instruments for generation of stereo-orthophotos. The most efficient variant of a stereo-orthophoto subsytem is the one with automatic stereo-orthophoto generating components equipped with on-line scanner-correlators that are capable of performing the auxiliary pictorial-to-numerical conversion required for the printing of the stereo-orthophotos. Besides simultaneous printing of orthophotos and stereomates, these components perform the role of the subsystem for compilation of information on elevation by automatically generating the digital terrain models. If necessary the contours can be, in this case, generated again by an independent numerical-to-numerical conversion using the computing facilities of the land information system. Being in principle analytical instruments, these components can also use the adjusted coordinates and the parameters from the "control files" to reconstruct the models without repeating the external orientation.

The part of the subsystem concerned with the compilation of information on features that is based on stereocompilers, allows for the use of simple and fast compilation techniques after a minimal preparatory work on the orientation of the stereo-orthophotos (i.e. shifting and rotation of stereomate in its own plane). The digitized information is fed from the subsystem into the external storage devices of the land information system via the editing facility enhanced by the editing techniques inherent in the design of stereocompilers. This compilation subsystem allows for a more complete exploitation of the collected information in the land system's data base by supporting the generation of various output forms with combined pictorial and graphical presentation of information such as orthophoto maps with various line-drawn overlays. Also, the field work related to the establishment of a data base comprising field checking, interpretation and collection of semantic information that is not contained in the original photographic records, can be conveniently based on orthophoto mosaics and on stereo-orthophoto prints instead of the original aerial photographs. In general, it can be stated that a photogrammetric information compilation system composed of the described subsystem for compilation of detailed information and an analytical plotter-based control densification subsystem, represent an economical and effective variant well-suited to the needs of an integrated multipurpose cadastral information system, due to the ease with which it can be exploited by various users, and due to the flexibility in its organization which permits its adaption to a fully centralized cadastral system as well as to a cadastral system administratively organized into a network with the activities distributed between the central office and the regional offices of the country (van Wijk, 1982). It should be underlined that a stereo-orthophoto-based compilation subsystem whose stereo-orthophoto generating components do not have the capability to compile the necessary auxiliary digital information on terrain elevation, and which perform the printing of the orthophoto and the stereomate in a sequential mode, represents a substantially restricted alternative. In this case the optimal configuration of the subsystem is upset by the need for some additional components for generation of digital terrain models or profiles, and to a lesser degree by the sequential instead of the simultaneous generation of the orthophotos and stereomates.

These examples of possible configurations of on-line photogrammetric information compilation systems, although by no means exhaustive, are sufficiently demonstrative of the capability of analytical photogrammetry to satisfy practically any requirement that may be posed by a geo-coded information system. It is evident that, by careful system analysis, a proper selection of hardware and software can be made, and the optimal version of the compilation system determined. However, these examples also indicate implicitly the need for further development of procedures, based on the mathematical tools of operations research, that will enable both the system designers and the users to objectively evaluate the advantages and deficiencies of various hardware configurations and software designs.

INSTRUMENTATION FOR PHOTOGRAMMETRIC DIGITAL IMAGE PROCESSING

There are four categories of images or records which could be considered as carriers of input information for photogrammetric processing and analysis:

- original analog images (e.g. frame camera photographs)
- original digital images (e.g. array camera records)

- derived analog images (e.g. stereo-orthophotos, array camera records converted into pictorial form)
- derived digital images (e.g. digitized frame camera photographs)

The photogrammetric instrumentation presently used in production is designed for processing of original and derived analog images and has the capability for the performance of processes with satisfactory accuracy and efficiency. In the last years the first steps have been taken towards the design of photogrammetric digital image processing instrumentation for processing and analysis of original and derived digital images. The basic motivation for this development is the full exploitation of the potential offered by the advances in computer and digital image processing technologies (Case, 1982). It is expected that in the end, computing devices with appropriate display units may replace the conventional photogrammetric hardware for data processing, and shift the development of processing techniques and related functions entirely into the realm of software design.

This could be viewed as the natural extension of the concepts underlying the design of analytical instruments in which the digitizing of information stored on analog images occurs at the compilation stage and encompasses only the information about selected features. It is worth noting that the processing techniques of properly designed analytical instruments allow for the exploitation of all the imagery acquired by any kind of sensors from airborne or space platforms under the provision that the digitally acquired records are converted into an appropriate pictorial input form. The main deficiency of this approach is the incompatibility of conventional techniques for metric information processing with the image manipulation processes inherent in the techniques of digital image enhancement and analysis. Hence, the design of a digital photogrammetric system that would permit the unification of photogrammetric digital processing techniques with the techniques of digital image analysis seems to be a worthwhile objective. Such a system would allow for simultaneous exploitation of digital processes used in photogrammetry for the processing of metric information, of digital processes used in analysis of remotely sensed data (such as edge enhancement, contrast stretching and classification), and of digital processes used in image understanding, image matching and change detection (Rosenfeld, 1984). Consequently in a digital system of this type the potential for automation of processes should also be considerably increased.

Instead of selective digitizing of information the concept of photogrammetric digital image processing implies the existence of original input information obtained by the conversion of an analog image into a numerical form represented by a two-dimensional array of digital gray level samples (Helava, 1982). The development of linear array cameras capable of acquiring from space platforms stereo-images with good base to height ratios indicates the possibility of using original digital records for production and revision of maps. However the very small image scales, the limited attainable spatial resolution of sensors, the stringent requirements for the stability of the spatial attitude of the sensors and the continuity of forward movement of the platform combined with the relatively complex quasi-cilyndrical geometry of images ("pushbroom" mode of image formation) will impose limitations on the interpretability of desired features and on the extraction of metric information. Even with the anticipation of the improvements of spatial resolution of sensors these imagery may be most optimistically expected to be used for revision of maps in 1:100 000 and mapping in smaller scales (Welch, 1982, Konecny et al., 1982, Chevrel et al., 1981). Consequently for a long time to come, due to the requirement for the information of high metric quality, most of the source information will be acquired in analog form by precise, well-controlled photogrammetric cameras from airborne and space platforms. Hence most of the information to be processed by a digital system has to be converted into digital form by scanners. Therefore the analysis of scanning and quantizing techniques with respect to scanning speeds and minimal entropy of information is an essential task to be addressed.

The next critical area of concern is the storage of the digitized information. Assuming that 256 levels of gray are satisfactory each picture element (pixel) requires one byte. If a standard 23cm x 23cm photograph is converted into an array of 10μm pixels (which already implies some loss of information) the resulting array would require a storage space of 529 Mbytes. This indicates not only the enormous requirements for storage space on external memory devices but also the problems related to the access times and the size of necessary random access memory.

It is evident that a photogrammetric digital image processing system should be able in the first place, to perform all the photogrammetric processes and functions that are performed by the conventional photogrammetric equipment. It is worth noting that some of the functions and processes that can be simply and efficiently carried out for instance on analytical instruments are quite difficult to implement in a digital system. Even the performance of simple elementary processes such as the image rotation with scale change, the tracing and measuring in dynamic mode at acceptable roaming speeds and the pictorial displays of stereo images require for example the resampling of large arrays, the implementation of special algorithms and the special hardware support for fulfillment of conditions imposed by real-time functions. The problems are even more complex on the higher levels of merging the digital photogrammetric techniques for processing of metric information with the techniques of digital image analysis where some of the latter techniques (e.g. edge enhancement) may adversly influence the metric quality of images. Consequently it is evident that the design of a universal photogrammetric digital image processing system represents a difficult and expensive long-term task.

DIGITAL SYSTEMS FOR PHOTOGRAMMETRY OF DYNAMIC PROCESSES

The technological advances in the development of solid state cameras with two dimensional arrays of detectors have contributed to the implementation of the concept of genuine or true real-time digital photogrammetric techniques. The main characteristics of solid state cameras (also called matrix or array cameras) are: high speed of analog-to-digital conversion, direct digital storage of images into memory at frame rates of 30Hz and higher, stability, wide spectral range, and small size. The detectors in the arrays may be charge-coupled devices, charge-injection devices or photo diodes. The digital image storage is the same two dimensional array of pixels (digital gray level samples) as the one already mentioned in connection with scanning and digitizing of photographs. On the basis of these characteristics it is evident that solid state cameras (which are in a sense the digital counterparts of analog frame cameras) combined with appropriate high speed computing devices and fast access memory devices represent the technological foundation for a new branch of photogrammetry that could be named "dynamic photogrammetry".

Despite the low resolution of presently available solid state cameras (typically ~ 400x500 pixels and exceptionally ~ 1000 x 1000 pixels) the instrumentation build around them has already proven its capability for real-time measurement, monitoring and control of dynamic processes (Real and Fujimoto, 1984). The meaning of real-time in this context implies the possibility to perform the acquisition, measurement, processing and analysis of data during the occurance of the dynamic processes (or phenomena). In cases where the dynamic changes are under control of some devices (as in feedback systems) the real-time photogrammetric image processing includes the determination of control parameters (or signals) based on the algorithms for decision making. Typical examples of areas for application of true real-time digital techniques are medical diagnostics, production control and robotics. In general the digital photogrammetric instrumentation of this type and the associated software based in part on algorithms and techniques of artificial intelligence, are the elementary components of machine-vision systems for "intelligent" machines, which are the basic systems for automation of manufacturing and other processes.

CONCLUDING REMARKS

As can be perceived from this broad-brush review of innovations and developments, considerable changes in photogrammetry as a discipline are under way. Notwithstanding the considerable difficulties with reorientation and reorganization in photogrammetric practice, instrument manufacturing and education, due to these changes, it is evident that a foundation for future development of the discipline and its expansion into new areas of application has been firmly established.

In conclusion it should be noted that the term photogrammetry does not fit well with a number of new concepts and techniques. It seems that in its process of evolution the discipline has outgrown its name. In the context of new developments and areas of activities the term photogrammetry should be understood to represent a general discipline for image metrology and image interpretation.

REFERENCES

Baker, H.H., Binford, T.O., 1982, A System for Automated Stereo Mapping. Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 156-167.

Case, J.B., 1982, The Digital Stereo Comparator/Compiler (DSCC). Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 23-29.

Chevrel, M., et al., 1981, The SPOT Satellite Remote Sensing Mission. Photogrammetric Engineering and Remote Sensing, Vol. 47, No. 8, pp. 1163-1171.

Helava, U.V., 1982, Fundamentals of Stereo Scanning. Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 182-200.

Horn, B.K.P., 1983, Non-Correlation Methods for Stereo Matching. Photogrammetric Engineering and Remote Sensing, Vol. 49, No. 4, pp. 535-536.

Jaksic, Z., 1980, Evaluation of Functional and Structural Characteristics of Analytical Plotters. Proceedings of the XIVth ISP Congress, Hamburg, F.R. Germany, International Archives of Photogrammetry, Vol 23, Part B-2, pp. 106-116.

Jaksic, Z., 1981, On-Line Computational Photogrammetry in Geocoded Information Systems. Proceedings of the XVI FIG Congress, Montreux, Switzerland, Commission 5, 510.6, pp. 1-13.

Konecny, G., Pape, D., 1981, Correlation Techniques and Devices. Photogrammetric Engineering and Remote Sensing, Vol. 47, No. 3, pp. 323-333.

Konecny, G., et al., 1982, Investigations of Interpretability of Images by Different Sensors and Platforms for Small Scale Mapping. Proceedings of ISPRS Commission I Symposium, Canberra, Australia, International Archives of Photogrammetry, Vol. 24-I, pp. 11-22.

Kratky, V., 1982. Recent Progress in the NRC On-Line Photogrammetric Triangulation. Proceedings of the ISPRS Commission III Symposium, Helsinki, Finland, International Archives of Photogrammetry, Vol. 24-III, pp. 284-295.

Pekelsky, J.R., 1982, The Superposition Comparator: Motion-Error Immunity in Photo Coordinate Determination. Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 56-72.

Real, R.R., 1982, Fast Digital Image Enhancement for Video Image Transfer in Photogrammetric Instruments. Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 201-212.

Real, R.R., Fujimoto, Y., 1984, Digital Processing of Dynamic Imagery for Photogrammetric Applications. IEEE Transactions on Instrumentation and Measurement, Vol. IM-33, pp. 45-51.

Rosenfeld, A., 1984, Image Analysis: Problems, Progress and Prospects. Pattern Recognition, Vol. 17, No. 1, pp. 3-12.

Slama, C.C., 1982, Generalized Software for Analytical Plotters, Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 102-109.

van Wijk, M.C., 1982, Instrumentation for Land Information Data Acquisition Based on Stereo-Orthophotos. Proceedings of ISPRS Commission II Symposium, Ottawa, Canada, International Archives of Photogrammetry, Vol. 24-II, pp. 110-116.

Welch, R., 1982, Image Quality Requirements for Mapping from Satellite Data. Proceedings of ISPRS Commission I Symposium, Canberra, Australia, International Archives of Photogrammetry, Vol. 24-I, pp. 50-54.