Zeitschrift: Vermessung, Photogrammetrie, Kulturtechnik : VPK = Mensuration, photogrammétrie, génie rural

Herausgeber: Schweizerischer Verein für Vermessung und Kulturtechnik (SVVK) = Société suisse des mensurations et améliorations foncières (SSMAF)

Band: 83 (1985)

Heft: 9: Sonderheft zum Rücktritt und 70. Geburtstag von Prof. Dr. Dr. h. c. H. H. Schmid

Artikel: Digital photogrammetric mapping

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DOI: https://doi.org/10.5169/seals-232623

Digital Photogrammetric Mapping

J. M. Zarzycki

Introduction

In the last decade, photogrammetry has experienced an almost revolutionary change which was brought about by the rapid development in computer technology and particularly computer graphics. Not only have the design concepts of photogrammetric instruments evolved from analog to analytical approach, but also the collection and display of data has changed from analog (graphical) to digital methods. Terrain data obtained by photogrammetric means are now registered in digital form, stored on magnetic discs and tapes, displayed on CRT terminals, and automatically drawn using ‹intelligent› drafting tables. The graphic manuscript is replaced by digital data file, and the graphic data base is replaced by a topographic digital data base.

We are now capable of creating a *Digital Map* which is independent of cartographic representation. It is a digital depiction of the terrain in which all terrain features are properly classified, coded, organized and stored so that they can be retrieved, managed and manipulated by a multitude of users. A Digital Map is not tied specifically to a single application and does not have a scale.

The *Digital Map* is a flexible tool in the hands of many professionals engaged in mathematical modelling, geographiical information systems, and production of graphical (map) representation of the terrain. However, one must be fully cognizant of the fact that simple digitalization of details from aerial photographs will not result in a true Digital Map which is capable of satisfying a multitude of analytic and graphic application. The degree of usefulness of digital terrain information and consequently the economic benefits of digital mapping will depend on the degree of sophistication of the classification systems of topographic features, an effective reference system of all data and a file structure that provides for extensive data base management operations. The Digital Map must not only provide capabilities to satisfy general cartographic data processing, but must be capable of providing the base for geographically referenced information systems.

Photogrammetric Digital Mapping

The development of interactive graphic data collection and editing systems has made digitization with photogrammetric instruments practical and economic. The system developed at Topographical Survey Division (Fig. 1) gives the stereoplotter operator unrestricted access to the digital data of the stereo model he is compiling, and of the surrounding stereo models that have been compiled by him or others. The stereo-operator is called upon to concentrate on the aspects of accuracy and completeness within a stereo-overlap and does not become involved in the consideration of whether a particular subject of his data is to be displayed on a particular map sheet.

The operator may view the digitized features at any scale on a CRT and perform any necessary corrections or editing. He can tie in adjacent stereo models and make any required changes to the digital data. He has the same freedom to interact with digital data that he normally has on a pencil manuscript in the graphical compilation mode.

In digital mapping, two basic types of digital files should be considered:

1. Position File
2. Representation File

The Position File contains edited and checked data collected directly in digital form on photogrammetric instruments. In this file all topographical

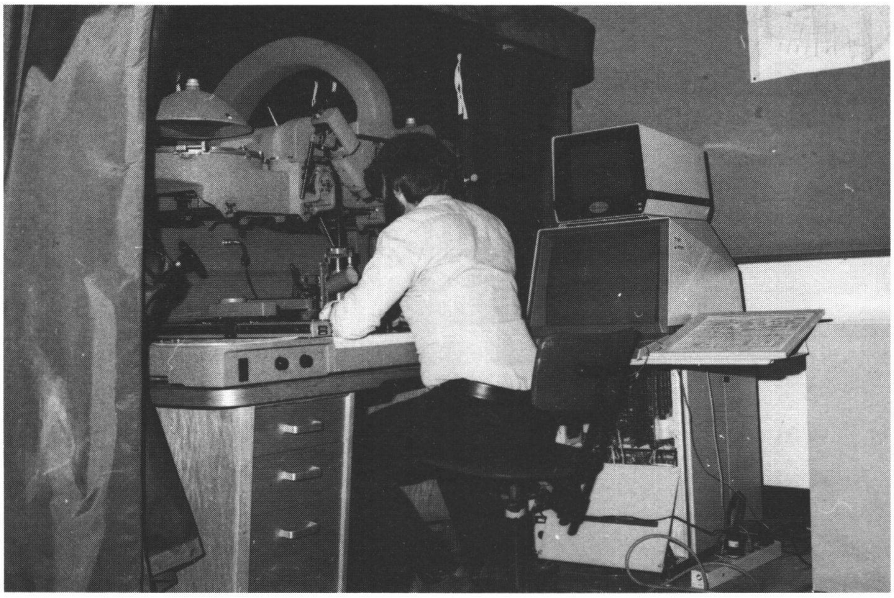

Fig. 1

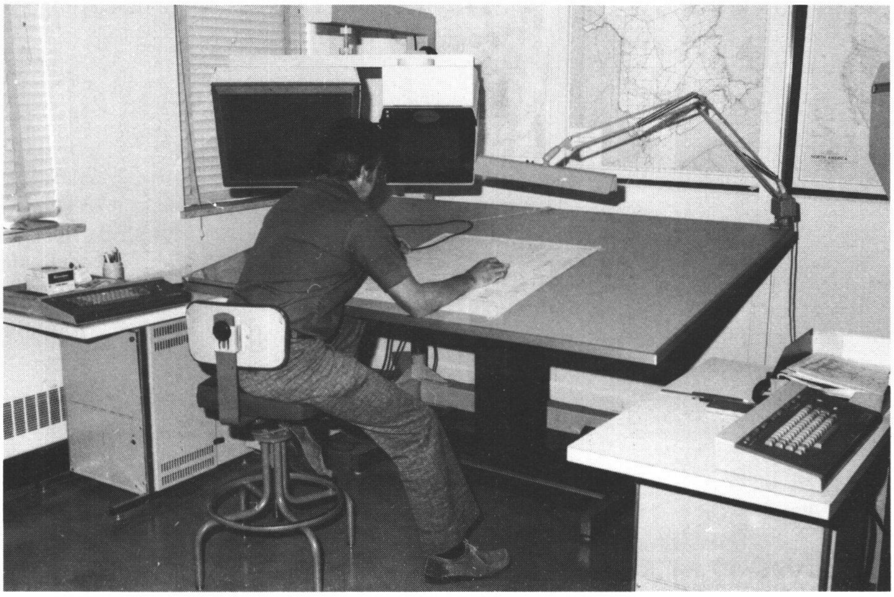

Fig. 2

features are recorded in their ‹true› geographical positions, without regard to cartographic symbolization.

The Representation File is created by the cartographer for each scale of map from the Position File. A computer assisted interactive graphic system (Fig. 2) permits the cartographer to displace or delete features, select the proper symbols, then issue appropriate commands for the automatic drafting of colour separation negatives.

Initially, data acquisition is by stereo-model with ‹edges› from adjoining stereo-models being ‹taken›, that is data is *removed* from the data file of the previous stereo-model and *entered* in the new file. This prevents redundant data in the data base structure. Each stereo-model is compiled fully without regard to any map sheet boundaries. Subsequently, data files, of any size, are created by a ‹clip process›.

The clip process, whether for position file (.POP) or representation files (.REP) is identical. The first step is to create a destination file in which a closed polygon, ostensibly, then neatline of a map or a ‹popfile› outline, is defined. The originator may at this time employ a number of options to further select data to be actually transferred. The options are somewhat generalized and are not intended to be used for feature by feature selection. Examples of choices available would be the inclusion/exclusion of textual information or features not required for reproduction such as model neat lines.

The process continues with the definition of the source files. These are files in the standard data base structure which may be entirely within the clipping polygon, overlapping in part or in whole, or even not overlapping at any point. The process places no limitation on the number of source files and may be used to merge data from a number of individual sources, including files not created by photogrammetric compilation, into a single destination file.

The polygon for clipping is not directly limited except that the present implementation has an established maximum of 25 vertices. This limit has no implications in terms of neatlines for standard mapping and was selected to enhance system operations. With judicious use of the process and options it is possible to create graphics whose content and display (orientation and coverage) can be tailored to most requirements (Fig. 3).

The accuracy of the topographical data acquired by graphical methods and then subsequently digitized is always constrained by the compilation scale. However, this is not the case when terrain data is digitized directly in the stereoplotter. Whereas in the traditional mapping process the original graphic manuscript compiled photogrammetrically at a given scale is the limiting factor governing the accuracy of topographic data, in digital compilation, the accuracy of the data is limited by the scale of the photography and the visual accuity and manual dexterity of the photogrammetric operator. The accuracy of the digital data is independent of the map scale. There is no displacement of features to avoid crowding and no slippage of the scribing tool in following a difficult line. The digital data compiled photogrammetrically is always of a higher accuracy than on the resulting graphics. Thus, maps at several scales can be automatically drawn from the same photogrammetrically acquired digital data, and the graphic accuracies that are standard for each scale are maintained on the final products.

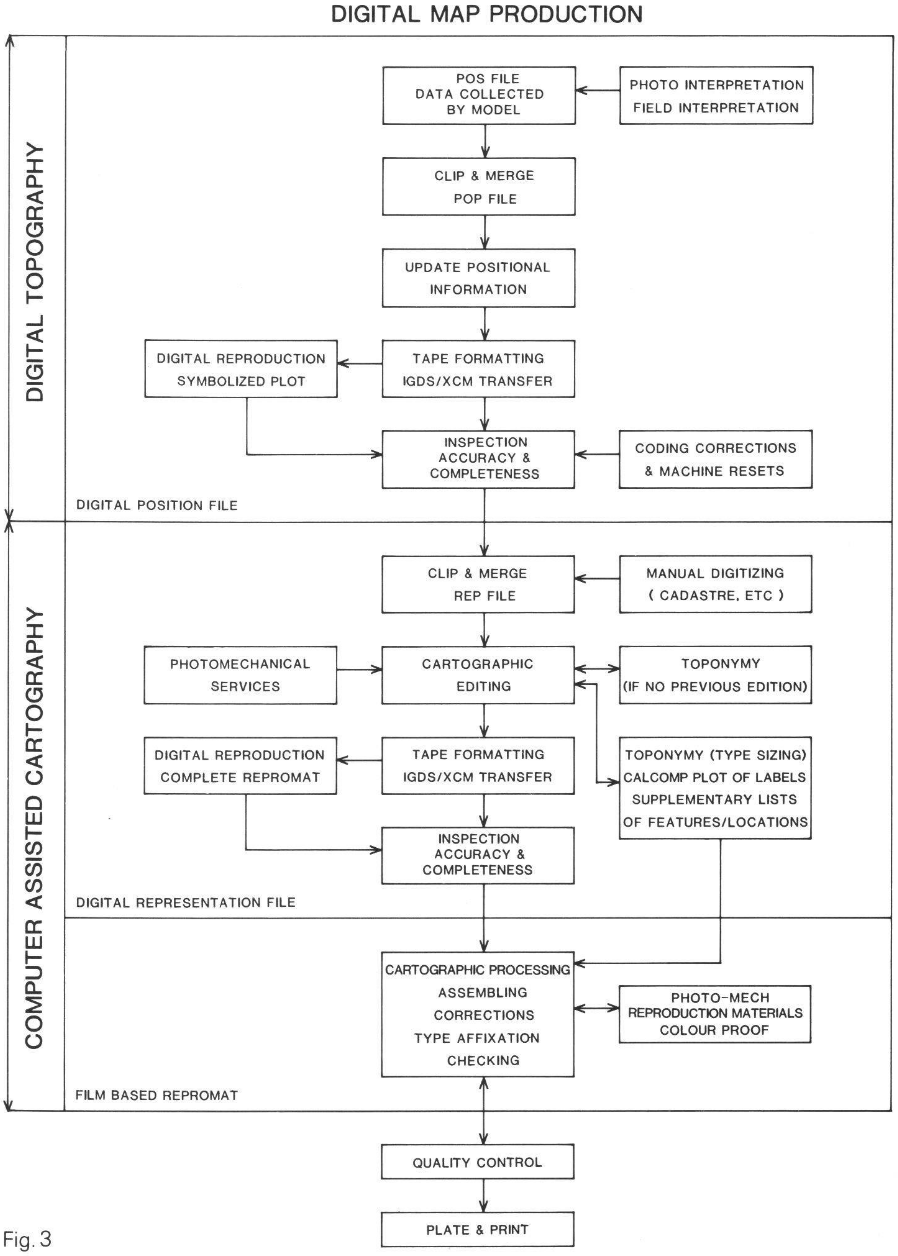

Fig. 3

Economics of Digital Mapping

The performance of the digital mapping system is often measured vis-à-vis traditional manual methods with little regard being given to the value of the digital topographic data base from which, in addition to digital applications, a number of graphic products can be produced on demand. Evaluation of the cost and efficiency of digital mapping must take into account the value of the digital data in addition to the graphical products derived from it.

The cost effectiveness of sophisticated digital mapping systems employed exclusively for the purpose of producing graphics by means of automated drafting table, and desregarding completely the value of digital data, is questionable at best. The actual or perceived savings in manpower cannot, at present, offset the substantial cost of capital equipment.

Graphical outputs can be produced semi-automatically by other simpler means. We have on the market several ‹intelligent› drafting tables which can be attached to stereo plotting instruments in place of the older type tables. This innovation reduces significantly a number of manual drafting operations at large map scales, and although such machines will not produce the quality of product of a sophisticated digital mapping system, they are considerably less expensive and simpler to put into production.
The economic viability of a sophisticated digital mapping system depends on the value we put on the digital data base; a data base which will provide a foundation for a geographically referenced terrain information system and for production of a multitude of graphics. The value of this data is not difficult to perceive, but it is difficult to quantify.
In terms of the process to be used in acquiring digital data, in the case where new compilation is needed, it is more economical to collect the topographical data directly on the stereo plotting instrument than to first compile conventionally and then digitize the resulting graphical manuscript.

Need for Standardization

Increasing use and acceptance of digital mapping and the proliferation of systems necessitates development of standards, so that digital data can be widely exchanged. Ideally, the same topographical feature, whatever it be, a road, house, property boundary or a telephone line, should be digitized only once by whatever organization has the first need for this data and then supplied to other users. Such an ideal situation may be only a dream despite best efforts on everyone's part.
However, in the digital area, duplication of effort can be substantially reduced if there is good will on the part of all concerned. A uniform digital data base which would satisfy the needs of all organizations is not feasible, nor is it required in order to achieve the objective of exchanging digital terrain data. What is needed, however, is a National Standard for the Exchange of Digital Terrain Data which will facilitate communication between distributed data bases. These standards should cover three aspects:

1. Classification (taxonomy) of topographical features including definitions.
2. Standards for geometric accuracy, precision and level of topographic content of digital data.
3. EDP standards as applied to digital topographic data.

In Canada, we are now in the process of publishing the National Standards for the Exchange of Digital Topographic Data. A draft of these Standards is now available.

Conclusion

Digital mapping technology with the related interactive display systems has opened new horizons to our professions. Digital topographic data is the base for all geographically referenced earth science and land information systems.
The almost unlimited flexibility of digital data will most likely result in user demands for specific information and for greater variety of data than is commonly the practice with graphical data bases.
The users will be able to interrogate digital topographic data bases and view a map displayed on a CRT in their office or a TV screen in the convenience of their living room. They will be able to select the area of their interest, examine perspective views of the terrain and obtain a paper print of it in their office or at home before taking a vacation trip.
Digital mapping opens new and almost unlimited horizons to the photogrammetric profession. It is incumbent on us to face the challenge of this new technology with confidence and to take advantage of the new opportunities.

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Die Bedingungsgleichung in der Ausgleichungsrechnung

H. Zollinger

Ein Gleichungssystem kann grundsätzlich geschrieben werden in der Form:

$$\mathbf{F}(\mathbf{y}) = \mathbf{O} \quad (1)$$

Der Vektor $\mathbf{y}$ beinhaltet Parameter, welche unbekannte (zu bestimmende) Grössen $\mathbf{x}$ und bekannte Grössen $\mathbf{L}$ bezeichnen. Falls das System redundant ist (mehr Gleichungen als unbekannte Grössen) und die bekannten Grössen im Sinne von Messwerten nicht widerspruchsfrei vorliegen, ist eine Ausgleichung unumgänglich. Die Methode der kleinsten Quadrate verlangt nach einem linearen Gleichungssystem bzw. einer Linearisierung von (1):

$$\mathbf{A}\mathbf{v}_\mathbf{L} + \mathbf{B}\Delta\mathbf{x} = \mathbf{w}_\mathbf{L}\ ;\ \mathbf{P}_\mathbf{L} \quad (2)$$

Die Messgrössen (Beobachtungen) erfahren – aufgrund ihrer Widersprüche – Verbesserungen $\mathbf{v}_\mathbf{L}$, während die Näherungswerte $\mathbf{x}^0$ für die Unbekannten mit $\Delta\mathbf{x}$-Werten zur Lösung $\mathbf{x}$ beaufschlagt werden.
In Abhängigkeit ihrer Genauigkeit wird den Beobachtungen ein Gewicht p_i bzw. dem ganzen Satz eine Gewichtsmatrix $\mathbf{P}_\mathbf{L}$, die die Einführung von Korrelationen erlaubt, zugeordnet.
Die Ausgleichungsbedingung

$$\mathbf{v}_\mathbf{L}^T \mathbf{P}_\mathbf{L} \mathbf{v}_\mathbf{L} = \text{Minimum} \quad (3)$$

führt mit der Nebenbedingung (2) zum bekannten Normalgleichungssystem

$$\mathbf{B}^T(\mathbf{A}\mathbf{P}_\mathbf{L}^{-1}\mathbf{A}^T)^{-1}\mathbf{B}\,\Delta\mathbf{x} = = \mathbf{B}^T(\mathbf{A}\mathbf{P}_\mathbf{L}^{-1}\mathbf{A}^T)^{-1}\mathbf{w}_\mathbf{L} \quad (4)$$

(2) ist die allgemeinste Formulierung von Ausgleichungsproblemen: Sie wird in der klassischen Ausgleichungsrechnung als Lösung von ‹bedingten Beobachtungen mit Unbekannten› bezeichnet. Gilt $\mathbf{A} = \mathbf{I}$, so liegt der Fall der ‹vermittelnden Ausgleichung› vor; ist $\mathbf{B} = \mathbf{O}$ (wobei $\mathbf{A} \neq \mathbf{I}$), wird damit die ‹bedingte Ausgleichung› formuliert (die Lösung kann dann natürlich nicht über (4) gefunden werden!).
Wenden wir uns (zusätzlichen) Bedingungsgleichungen zu, die sich ebenfalls ganz allgemein anschreiben lassen:

$$\mathbf{G}(\mathbf{x}) = \mathbf{O} \quad (5)$$

Unter einer Bedingung wird gewöhnlich eine sich auf die unbekannten Grössen $\mathbf{x}$ beziehende Forderung verstanden, z. B.:

$$x_1 = x_2 \quad (6)$$

oder aber auch eine Wertzuweisung, z. B. also:

$$x_1 = a \quad (7)$$