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INTERACTIVE DATA CAPTURE WITH ANALYTICAL PLOTTERS

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1. Introduction

First attempts with digital elevation models (DEM) in which the height information is given in a regular - usually gridded - pattern have shown the need to assess, possibly at an early stage, the quality and the precision of the DEM. Makarovic |7| has been one of the first photogrammetrists to point out this fact with his path-finding research on progressive sampling. Others have encountered this phenomenon while generating contour lines from a DEM. Ackermann, in his paper |1| presented at the ASP DTM Symposium at St. Louis in 1978 stated that "...it has been shown that the resulting accuracy depends to a great extent on the appropriate data acquisition, in fact more than on anything else". This has always been true with contour lines and there is no reason why this should change with gridded data and the derivation of contours thereof or vice versa.

The problem is twofold: first, it seems difficult to define terms like quality and precision of a DEM. It can be done mathematically as shown by Förstner |4| , but a DEM is rarely created "per se", there is always a particular application at its origin and very often, its future users are unable to define their priorities. Secondly, quality and precision tests have to be done interactively during the data acquisition phase on a photogrammetric model. The operator should not be unnecessarily delayed during the data acquisition phase and the computer should guide him with simple, clear instructions. Considering the complex computations needed to obtain the necessary information, this looks like a formidable task in an on-line environment. Therefore, only closed-loop systems with fast computers seem able to cope with the situation, meaning that the practical choice is limited to analytical plotters.

Even if correlators become eventually available on analytical plotters in the not too distant future, experience with automatic systems such as the GESTALT-PHOTO-MAPPER II shows that human intervention will remain at a relatively high level and that similar decisions have to be taken by the operator |3|. Putting it simply, one may say that with correlators the emphasis will be more on data compression and filtering rather than on data completion, but the interactive part will not entirely be eliminated.

2. Concepts of Interactivity

Through practical experimentation on analytical plotters (to be discussed in more detail further on) some ideas of an ideal photogrammetric data acquisition system have emerged, though it has to be mentioned that the experiments were mainly done with DEMs. Therefore, an extrapolation of these findings towards more general data acquisition (including e.g. planimetry) would need some further investigations. The different components of such a system are presented in Figure 1:

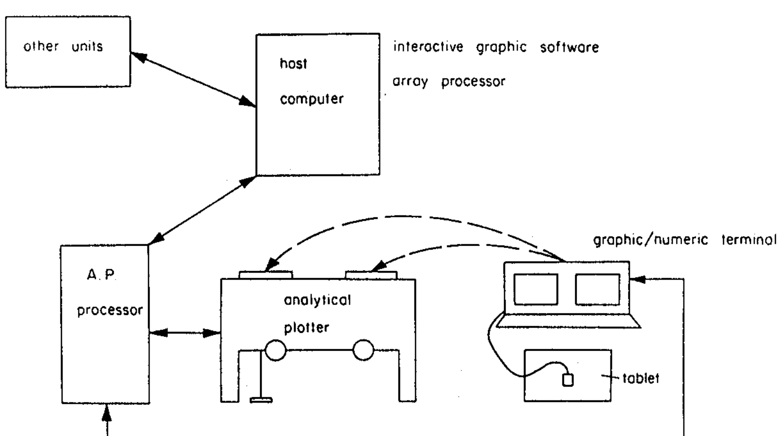

Fig. 1 :
Elements of an interactive system

A configuration similar to the one described in Figure 1 is installed at the Swiss Federal Institute of Technology in Zurich |6|, on which some experience could be gained. One may ask for the justification of adding additional hardware elements to the basic analytical plotter configuration. The answer is rather complex:

1. Photogrammetric height data collection in practical applications means bulk data processing. In order to be able to analyse the product, some kind of fast graphical representation is mandatory.
2. Interactivity must not strain the operator. On-line checking of the completeness and quality of his work are greatly facilitated if the data can be optically superimposed to the stereo-model.

As the operator is mainly working on only one stero-model, not all the data have to be available for fast access at any time with the exception of inter-model ties and scanning activity. The link to the host computer needs therefore only to be activated for fast transfer of data.

On the other hand, computer requirements for interactive graphic software are not known to be modest and usually exceed the capacity of the analytical plotter processor. Besides, if the DEM has been captured in gridded form, an array processor could be extremely beneficial to further data processing. Tests done lately at Laval University with an array processor and a PDP 11/44 look very promising. Array processors can also be of great help for the interpolation of contour lines or other similar features. It has also been found that software which has primarily been developed for remote sensing applications can be adapted to photogrammetric requirements.

The optical projection of the screen (or, more general, of the graphic display of the captured data) into the stereo-model has yet to find an optimal solution. INTERGRAPH is offering this possibility as an option with their graphic software package; the Photogrammetric Department of NRC in Ottawa, the Federal Institute of Technology in Lausanne (Prof. Kölbl), have, among others, been working on it but no real breakthrough has been realized in this direction and further research needs to be done.

3. Interactive data capture

In |6|, results and conclusions of tests done with interactive DEM capture have been presented by Leupin et al., based on previous research done by Ayeni |2|, Frederiksen, Jacobi, Justesen |5|; Rüdenauer |8| and others. The main conclusions of these practical experiences were the following:

1. It is feasible to achieve excellent height accuracy with gridded DEMs, if the density of the grid is kept dynamic in order to adapt to varying topography.
2. With this optimal grid density, registration time can be reduced to 33% as compared to contour plotting.
3. Gridded height data offer many advantages, one of them being retrieval speed.
4. Controlled lines derived from such a DEM show excellent morphological quality (if characteristic features have been digitized).

Several methods were used for the determination of the grid density, all of them based on the measurement of one or two test profiles in the stereo-model: tests based on a simple criterion like the curvature |8| and more complex methods like the use of powerspectra |5|,|9| and |4|. It is interesting to know that within the tested area (1 : 4,800 image scale, 400m x 400m) no significant difference between the methods was found.

More recently, additional investigations have been undertaken with the same raw material, in particular the generation of contours from DEMs (and vice versa) was studied using a new version of the program developed by Zumofen/Leoni |10|. These results were compared with two other interpolation programs available at Laval University. Accuracies were computed with the help of 75 check points and directly plotted contours with 50 cm equidistance. The latter yielded a mean height error of 11 cm and a maximum error of 27 cm.

Table 1 shows the results of the creation of contours with different interpolation programs. For all computation, the progressively densified grid DEM |6| was used.

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The results show that the obtained accuracy is practically independent of the interpolation method used and also equivalent to the directly digitized contours. A visual comparison of the different contour plots does not show evident morphological differences, although a more rigorous investigation should be made |4|. Cutting the mesh width in half (densifying the grid) doesn't increase the accuracy, a result which is in accordance with Förstner's findings and a confirmation of the grid densification process.

Program	mean height error (cm)	max. height error (cm)
Original contours	11	27
Zumofen/Leoni	11	23
Progr. 1	13	25
Progr. 2	12	27

Table 1 : Generation of contours

mean height error (cm)	max. height error (cm)
12	23

Table 2 : Creation of a grid from contours (5m x 5m)

Creating a regular grid from original contours is another task that occurs quite often, especially when existing maps have to be integrated into a gridded data base. The Zumofen/Leoni program offers this additional feature. In Table 2, the heights of the newly created grid (computed from the original contours) are compared to the original, directly measured grid heights. Some precautions have to be taken while digitizing the contour lines, as too many points on the contour could create problems with the triangular-shaped mesh of the Zumofen/Leoni program.

Again, the accuracy seems to be constant as compared to the reverse process, although a loss of information is inevitable when going from direct to derived observations. In a practical environment the question could arise whether this loss can be accepted or not. One may very well imagine situations where the answer would be negative.

4. Critical Review

Despite the many positive aspects of the method presented, quite a few problems remain - at least partly - unsolved, the most severe one being completeness:

Characteristic terrain features like breaklines, tops etc., have to be digitized separately. In the case of breaklines, the operator faces two questions:

- what is a breakline?
- where is this breakline located?

If the previously recorded DEM is dense enough, algorithms can be developed which detect and locate breaklines automatically. Recently, such algorithms have been evaluated at Laval University with moderate success: in many cases, it was up to the operator to make the final decision. This might be interesting for the operator, but rather time-consuming and highly dependent upon the professional quality of the operator. In other more complex cases, the algorithms failed completely.
The same problem arises with other local, characteristic features. Förstner has proven in his paper |4| that increasing the grid density does not necessarily improve the quality of the morphology. This has also been shown in the above mentioned practical tests. An improvement can rather be realized with additional curvature and slope measurements. Again, algorithms could be developed which, on the other hand, will run into the same trouble as previously shown.

Another important aspect is the permanent visualisation of the digitizing process for the operator. Displaying and superposing the DEM grid onto the stereomodel does not offer any particular advantage but for the detection of gross errors. If a fast contour interpolation program is at hand, contours can be generated once the DEM is completely digitized. This is still one of the best methods in assisting the operator, but it is to a certain extent only an indirect check.

In this area, much research and software development remains to be done. Evidently, the photogrammetric acquisition of a DEM is a far more complex task than the plotting of contour lines. The difficulties will only be overcome if the capacities of analytical plotters are fully exploited and if adequate software and hardware are developed.

5. Outlook

With the exception of military agencies, where DEMs are now a well accepted and powerful cartographic tool, not too many civilian applications have become known. The author is familiar with two Canadian projects in which a considerable amount of experience has been gained:

- the 1 : 50.000 Canadian national map (EMR)
- the 1 : 20.000 Québec province map (Société de Cartographie du Québec)

Needless to say that with the vast territory to be mapped the amount of height data is of colossal dimensions. Heigher project uses a gridded DEM, but both rely on digitized contours. The predicted collapse under this mass of data has not taken place and despite some inherent problems both projects do remarkably well.

The reason for choosing contour digitization is that such large projects are undertaken to respond to a particular need, in these cases topographic mapping with contour lines. Other users rarely have very distinct conceptions of height representation and easily adapt to the existing documents. Very often, especially in natural resource mapping, accuracy requirements are somewhat less rigorous than in pure topographic mapping. If in such cases a gridded DEM is needed (e.g. orthophotography), it can easily derived with adequate accuracy from contour lines.

This may put a damper on those advocating "universal" DEMs, but in front of the many difficulties to obtain this universality (if ever that can be done), a certain precaution can only be recommended. This, of course, does not mean that gridded DEMs have no future in cartography: they will prove most beneficial on many occasions and it is predictable that their demand and use will increase over the years. However, if that is to happen, additional research has to be done and more experience has to be gained; finding an answer to the following questions could be of particular interest:

- Can a DEM successfully be used at different scales? If yes, what are the software requirements (e.g. for data compression)?
- How important is the morphological quality of derived contours?
- How can the (very often subjective) intervention of the operator in the interactive work be confined?
- What is the cost/efficiency ratio?

As with many new things, the user will have to go through an acceptance phase and the success will depend on how well DEMs will respond to his needs.

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Abstract

In recent years, photogrammetrists have focussed their interest in digital terrain models mainly on such topics as interpolation techniques, but surprisingly enough not too much research has been done on photogrammetric data capture. This, however, is rapidly changing: with analytical plotters and interactive graphic systems now at hand, more and more interesting applications become known.

This paper first develops some ideas on interactivity with analytical plotters and, in second, presents some practical results of tests done at the Swiss Federal Institute of Technology in Zurich (where the author was spending his sabbatical during 1982) and at Laval University. In a final part, these experiences are discussed critically and recommendations for futures research are given.

INTERAKTIVE GELÄNDEERFASSUNG MIT ANALYTISCHEN SYSTEMEN

Zusammenfassung

Das Interesse der Photogrammeter an digitalen Geländemodellen hat sich in den letzten Jahren vor allem in Arbeiten an Interpolationsansätzen ausgedrückt, während der eigentlichen Datenerfassung eher wenig Aufmerksamkeit geschenkt worden ist. Der erleichterte Zugang zu analytischen Geräten und interaktiven graphischen Systemen hat eine Veränderung der Situation bewirkt. Mehr und mehr Arbeiten befassen sich heute mit photogrammetrischer Datenerfassung.

Zuerst werden instrumentelle und rechnerische Anforderungen für interaktives Arbeiten umrissen, während dann in einem zweiten Paragraphen einige experimentelle Arbeiten vorgestellt werden. Schließlich wird versucht, anhand der bisherigen Erfahrungen Bilanz zu ziehen und einige Empfehlungen zu formulieren.

SAISIE INTERACTIVE DE DONNEES DE TERRAIN PAR TRACEURS ANALYTIQUES

Résumé

L'intérêt des photogrammètres pour les modèles de terrain numériques s'est porté ces dernières années davantage sur des questions liées aux techniques d'interpolation, par exemple, que sur la saisie de données photogrammétrique qui n'a guère fait l'objet d'études. Toutefois, cette tendance est en train de s'inverser, favorisée en cela par la mise au point de restituteurs analytiques et de systèmes graphiques interactifs, propres à élargir le champ des applications offert.

Le présent exposé aborde dans un premier temps certains aspects des exigences mathématiques et instrumentales que pose la saisie de données interactive. Il présente ensuite les résultats de travaux réalisés à l'Institut de Technologie Fédéral Suisse de Zurich et à l'Université de Laval, avant de les comparer à ceux obtenus au Canada et de tirer ainsi les enseignements généraux de l'expérience acquisé à ce jour en la matière, tout en proposant pour conclure un cadre de recherche possible pour l'avenir.

RECOPILACION INTERACTIVA DE DATOS CON TRAZADORES ANALITICOS

Resumen

Durante los últimos años, los fotogrametristas han concentrado su interés en modelos digitales del terreno más bien sobre las técnicas de interpolación, mientras que la recopilación de los datos como tal ha sido objeto de estudios mucho menos profundos. Pero la situación ha cambiado esencialmente por el acceso más fácil a instrumentos analíticos y sistemas gráficos interactivos, de suerte que en la actualidad, está aumentando la cantidad de trabajos dedicados a la recopilación de datos fotogramétricos.

En la primera parte de esta conferencia se exponen algunas ideas acerca de las condiciones instrumentales y matemáticas para trabajos interactivos con trazadores analíticos. En la segunda parte, se presentan algunos trabajos experimentales, realizados por el autor en la Escuela Técnica Superior Federal de Zurich/Suiza, y en la Universidad Laval, de Québec/Canadá. La parte final de la presente conferencia corresponde a un análisis crítico de esta experiencia y en el mismo, se tratan de formular recomendaciones para futures investigaciones.

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