Digital Video Plotter DVP

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ABSTRACT

A popular, successful and accepted method of data acquisition for GIS databases is the photogrammetric compilation of vector data from remotely sensed imagery, normally aerial photography but also satellite images, especially SPOT. The companies which came together to form Leica have been producing instruments for many decades to enable customers to acquire photogrammetric data.

After a short introduction to Leica's recent history and its range of photogrammetric workstations, the emphasis in this paper is on the DVP Digit Video Plotter, an entry level digital photogrammetric station which consists of software capable of running on an ordinary personal computer together with a simple stereoscopic viewing device. The input to the DVP consists of digital images obtained by scanning photographic prints or diapositives. The output is a data file which can be easily translated into the user's in- house CAD or GIS system for further manipulation. The rationale behind the instrument is to provide an attractive and cost effective solution, based on standard hardware and straightforward software, thereby ensuring its appeal to a wide range of professionals, including not only parts of the usual photogrammetric market-place but also environmental managers, geographers, geologists, planners and the GIS and remote sensing communities. Its price level and the resemblance of its operations to those of an analytical stereoplotter ensure its future also as a training instrument.

Whereas analytical and digital photogrammetry are often presented as being distinctly different, resulting in disparate families of workstations, there is so much in common between the two that it is more constructive to build on the similarities and exploit the differences, for example the more tractable radiometric content of digital images. The paper is concluded with a short description of Leica's new SD2000, in which is explained paper is concluded with a short description of Leica's new SD2000, in which is explained the underlying principle of the photogrammetric workstation or "3D digitiser", whereby the photogrammetric functions are localised and easy communication provided to a host GIS, CAD or digital mapping system, and MAPIT, a software product to facilitate data collection for GIS.

1. AN OUTLINE OF PHOTOGRAMMETRIC PRODUCTS FROM LEICA

The use of photogrammetric methods in remote sensing is well known and needs no introduction here. The founder companies of the Leica group have a fine photogrammetric pedigree. Kern have been manufacturing photogrammetric equipment for 30 years and Wild, later Wild Leitz, for over 60. Between them, these companies accumulated an enormous share of the market for analogue stereoplotters, which enjoyed great success until analytical plotters began to supersede them in large numbers in the 1980s. The latter were better suited for remote sensing applications since their handling of different formats and geometries enabled a much wider range of imageries to be restituted.

Photogrammetry in Leica has experienced a rapid series of events which began with the purchase of Kern Aarau AG by Wild Leitz Holdings AG in 1988 and it is useful to summarise these with regard to the products which are useful in remote sensing. Two months after this merger, the latest analytical stereoplotters, DSR 12/ 14/15, together with the digital stereoplotter, DSPl, were launched at the ISPRS Congress in Kyoto. The DSRs were differentiated by their different host computers, PDP-11, personal computer (PC) and VAX, and the PDP-based DSR12 has subsequently been discontinued. Meanwhile the Wild BC2 was replaced in 1989 by the BC3, with a separate plate processor and a Unix host. The range of software offered with these instruments reflects the trend towards off-line or on-line linkages to destination CAD or GIS systems. Later in the paper there is a short discussion of the application of these instruments to SPOT imagery. In 1990, a further merger took place, between Wild Leitz Holdings AG and Cambridge Instruments Ltd to form Leica plc. Clearly, rationalisation would follow and early in 1991 the announcement was made that the factory in Aarau would close towards the end of the year, with photogrammetric manufacture being moved to the factory in Heerbrugg and product management and research and development, to a new business unit, Photogrammetry and Metrology Unterentfelden, which would be located in a suburb of Aarau and would be legally and admimstratively part of Leica Heerbrugg AG. By this time, the DVP had entered the product line. Shortly thereafter, Leica enjoyed the triumphant launch at the ASPRS/ACSM Convention in Baltimore of its new analitical plotter SD2000. The RC2O aerial camera and the range of stereoscopes have been relatively unaffected by these changes and continue to be developed, manufactured and marketed in Heerbrugg. The high powered stereoscopes and zoom transfer devices from the former Bausch and lomb factory in Rochester, USA go from strength to strength, now within a Leica business unit Called Image Interpretation Systems Inc.

The most recent development in this progression was the signing in July 1991 of a Memorandum of Agreement between Leica and General Dynamics. This will enable the two companies to work together and, in particular, will promote the distribution through the Leica network, to the civilian market, of digital photogrammetric products from HAI Inc., a General Dynamics subsidiary. These products will play a significant role in the photogrammetric processing of remotely sensed imagery.

2. DIGITAL PHOTOGRAMMETRY IN LEICA AND THE DVP

The purpose of this paper is to give a description of the DVP Digital Video Plotter, an entry level digital photogrammetric station from Leica. Two recent overviews (Walker 1991; Cogan, Luhmann and Walker 1991) outline the DVP alongside the DSP1, Leica's high end digital photogrammetric workstation, and the Programmable Optical Measuring System for specialist close range applications. In contrast to the DSPl, which was Leica's first venture into digital photogrammetry and is a high performance solution aimed at specialist markets (Cogan et al. 1988; Cogan and Hunter 1989), the DVP is an economical digital photogrammetric station which runs on an ordinary PC. It makes no attempt to pan the images (Walker 1991), in other words the real time movement is limited to the measuring marks. Thus an inexpensive graphics card with only 512K RAM suffices. It could be classified as an instrument which is based on "off the shelf" components (Grün 1989; Lohmann et al 1990). In a classification based on performance and functionality, Dowman (1991 p.4) judges the DVP as a digital photogrammetric workstation with "limited performance and functionality but low cost".

The "state of the art" in digital photogrammetry is summarised in many review papers, for example Bethel (1990), Dowman (1990a, 1990b, 1991), Grun (1989), Grun and Beyer (1990), Helava (1988) and Lohmann et al. (1990). With regard to the DVP, however, it is worthwhile reiterating the merits of being able to work with digital images on standard computer displays with familiar user interfaces rather than complex and expensive arrangements of optics and mechanism; of having digital rather than analogue images, so securing access to their radiometric content and the possibility of facilitating measurement and information extraction by image processing and automation (Wroebel 1991); of increased operator convenience, for example because there is no need for instrument calibration and no possibility of parallax between measuring mark and image and because interior orientation need never be repeated; and of incorporating stereoscopic, colour superimposition of digital map data at almost no additional cost. The possibility of photogrammetric work with digital images is crucial in remote sensing, where so much of the imagery is digital at source and the production of film images for use in analytical stereoplotters may involve a reduction in quality.

There are, unfortunately, disadvantages too. High resolution digital images result in small fields of view on the screen which are unacceptably limited for those familiar with typical analogue or analytical stereoplotters. Real time panning is achieved but the hardware requirements are still neither trivial nor cheap, as evidenced by the solutions not only of the DSP1 but also of other manufacturers; thus the DVP offers the simpler and cheaper option of stationary images and moving measuring marks. Disk space is rapidly absorbed by digital images and archiving facilities must be provided. Those problems will recede, however, as computer technology advances.

Images must be in digital form, but most data for mapping is still captured on film. Digital imaging devices which offer performance comparable to aerial cameras are still at an early stage in their evolution. Thus aerial photographs must be scanned. At present, no ideal scanner exists: a scanner with a format which can accomodate 230 x 230 mm aerial photogrpahs in the form of negatives, diapositives or prints, in colour or black and white, with a resolution of perhaps 20 micrometres and a PC interface, all for less than 25,000 Swiss francs, in the dream. The numerous low cost scanner in the PC and desk top publishing worlds are usually A4 format and/or too low resolution. Until recently few scanners were offered which were suitable for photogrammetric purposes (Luhmann 1989), but high performance models such as the PS 1 PhotoScan from Zeiss (Oberkochen)/Intergraph (Faust 1990), the Rollei RS1 and the Vexcel VX2000/3000 (Leberl 1990) are now available. Users must be aware, however, of the volumes of data which these units can create: an aerial photograph scanned in black and white at a resolution of 50 micrometres occupies 21 megabytes, but at 25 micrometres it need 85 and at 10, 529; colour at least doubles these requirements and it takes two photos to make a stereo pair! Between these two groups of scanners are the Ranx Xerox 7650 and Sharp JX-600, each advertised as being 600 dots per inch (pixel size 42 micrometres), A3 format, easy to use and capable of outputting in TIFF format. Thus both have been successfully used with the DVP. Whereas the Xerox is restricted to prints, the Sharp is capable of accepting negatives and diapositives too and is colour, but naturally is more expensive and slower in operation.

Finally, there is a process of education: the new markets at which the DVP is aimed contain personnel who are familiar with computers but no photogrammetry, so a digital solution is deal, but the traditional photogrammetric community may find it more difficult to adapt to the new technology and lay down its myths, mystique and arcane instrumentation. Moreover, it is clearly very difficult to improve on the performance of the combination of aerial camera and analytical stereoplotter for conventional collection of topographic data.

3. THE DVP DIGITAL PHOTOGRAMMETRIC STATION

The DVP Digital Video Plotter (Fig. 1) is an entry level digital photogrammetric station which is based on a standard PC (Agnard et al. 1988; Gagnon et al. 1990; Boulianne et al 1990; Nolette et al. 1991). The software was written, as tool to help train students, in the Département des sciences géodesiques et de télédétection of Université Laval, Québec, Canada. In 1989, the commercial distribution was undertaken by a local land survey enterprise, Géomatique EMCO, which in 1990 formed a new company, Les Systèmes Photogrammétriques DVP Inc., to concentrate on this operation. In mid-1990, DVP approached Leica Aarau AG, which assumed sole and exclusive rights to distribute the product in November. At the time of writing (July 1991), approximately 30 DVPs were in use by distributors for demonstrations to clients, 30 in production and 10 in education, indicating a sales campaign in its early stages but experiencing success.

Fig. 1 - 1 DVP digital photogrammetric station.

The objective of the DVP is to provide photogrammetry to a potential userbase which in the past has been discouraged by either complexity or cost. The instrument runs under MS-DOS or PC-DOS on a standard PC (80286 or 80386) or PS/2 with a low cost graphics card and multisync monitor. The screen resolution is 800 x 600 or 1024 x 768 on the PC with ATI VGA Wonder or Ultra graphics cards respectively or 1024 x 768 on the PS/2 with an IBM 8514A card. The image files contain 256 grey levels, with, in the case of the ATI Wonder, a mapping to 64 for display. Refresh takes around 10 seconds on a PC with a reasonable disk controller and a small cache is created in RAM by the DVP software.

As explained earlier in the paper, there is no image panning. For comfortable stereoscopic viewing, the measuring marks move in the oriented model such that they always have equal y coordinates on the screen. Consequently, the right hand image is refreshed whenever the required image displacement exceeds half a pixel. Window selection and XY movement in the images are performed by means of a Summagraphics SummaSketch or compatible tablet, continuing the emphasis on standard, economical components, though of course users have to accept that a large hard disk and an archiving device such as a tape cartridge drive are essential. The half screens are viewed though a simple optical system, which both DVP and Leica have preferred to alternative methods of viewing stereoscopic images on computer displays. The windows selected by means of a paper print on the digitising tablet are confirmed on a small reference diagram at the bottom of the screen (lower right in Fig. 2). A function whereby new windows are displayed centred on the current positions of the measuring marks is available too. All commands can be issued through either the PC's keyboard or cursor buttons on the digitising tablet, together with basic screen menus which are available in several languages. Z movements in the stereomodel are controlled from the keyboard.

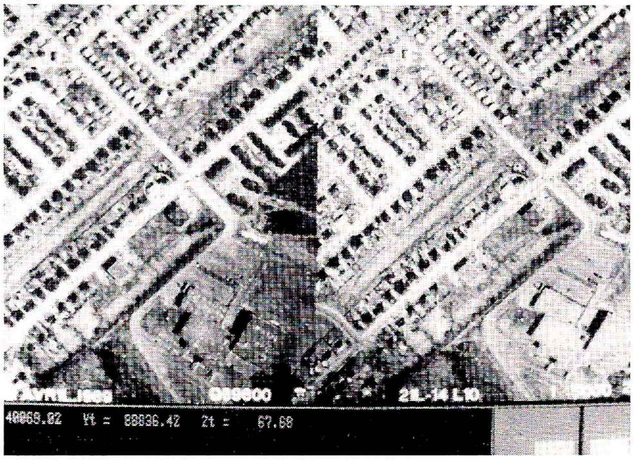

Fig. 2 - DVP screen layout during data collection from aerial photographs scanned at low resolution.

As discussed earlier, the DVP reads TIFF files, so images can be scanned on a low cost scanner from the desk top publishing industry. It is often sufficient to scan paper prints. Image processing is not offered, but several low cost grey scale editors are on the market which users could employ to "front end" the DVP.

The operations for workstation set up, orientation and data collection with two colour stereo superimposition are standard, but naturally there are fewer options, menu selections and displays than with the standard software on other Leica stereoplotters. A 2x zoom is implemented as an aid during orientation and a rudimentary image matching function can be chosen during relative orientation. DVP adhere to the philosophy of uncomplicated, productive data capture (Fig.2), after which the are translated into the format of powerful CAD or GIS systems for further work, namely ARC/INFO, AutoCAD or MicroStation. Two way translators are available so that existing data files can be brought to the DVP for stereo superimposition. A more sophisticated ARC/INFO translator is available from ESRI Canada. The DVP has also been intregrated with both Kork and Terra-Mar software products.

The DVP is targetted on a wide group of data users: land surveyors; environmental managers, in areas such as agriculture, forestry, and open casting mining; the GIS and remote sensing communities; planners in municipalities and the utilities; geologist and geographers; architects. The price of the DVP, its use of commonplace hardware and the fact that its operation emulate those of a typical analytical stereoplotter render it an ideal training tool.

Test have been encouraging (Nolette et al 1991). With wide angle photographs taken with 60% overlap at scales between 1:5000 and 1:4000 and scanned at 450 dots per inch, the results shown in table 1 were obtained. In all cases, relative and absolute orientation were performed with ten well distributed points and there were 20-50 check points. The results mean that root mean square errors in X or Y at well defined check points were about half pixel size. Thus planimetric accuracy is around 0.7 of pixel size and height accuracy has proved to be much the same. Experiences within Leica organisation confirm that these results are representative.

Table 1 - Accuracy of the DVP (Nolette et al. 1991 p 6)

Model	Rmse on check points (micrometres)	
	planimetry	height
1	34	35
2	40	34
3	45	35
4	42	42
5	50	33
mean	42	36

4. RESTITUTION OF SPOT IMAGERY

A version of the DVP for restitution of panchromatic stereopairs of SPOT imagery is almost ready. It is interesting to review the application of the various workstations in the Leica range to this problem. By 1987, work was already in progress on SPOT software destined for seven workstations - AC1, BC1, BC2, DSR11, DSR12, DSR15 and DSP1. In all cases, it was designed for use with Level 1A imagery. Kern drew on work by Gugan (1987, 1988), subsequently proven by Gugan and Dowman (1988), using the collinearity equations but allowing the parameters to vary through time, in other words in accordance with the y coordinate on the image. The ephemeris data were introduced in order to give the solution good initial values. The real time loop was based on the same model, which necessitated the use of a more powerful real time processor in the DSR11 on which the initial work was done. The spot software run first on the PDP host computer of the DSR11 and DSR12, then was ported to the VAX host computer of the DSR15 and DSP1. Several licences have been sold, but probably the best known project for which the product was used is the mapping work by the British in North Yemen (Hartley 1988; Murray and Farrow 1988).

At the same time, Gaugan's ideas were used by Aviosoft to write SPOT modules for the AC1 and BC1 stereoplotters with their Data General Nova hosts and for the BC2 with its DG30. Here the solution was obtained in a similar way to the Kern product, but the real time loop differed significantly. Discrepancies between a SPOT image with the computed orientation parameters and a central perspective image with the same parameters were computed for two Z planes and used to form 15x15 correction grids for the computation, via bilinear interpolation, of the image coordinates. The same approach was employed for the BC3 module, which was introduced in 1989 with the advantage of total integration with the MAPCE software for data collection.

Meanwhile, researchers in Australia (Trinder et al. 1988) had prepared an alternative module for the BC2, albeit with much less elaborate software for data collection than the Wild offering. The solution was again a modification of the collinearity equations, with the coordinates of the perspective centre varying as a second order function of the y coordinate in the image and the rotations, as a first order. The real time loop was implemented by dividing the image into segments, each with a different, but conventional, central perspective; image coordinates within each segment could then be corrected by means of second order polynomials in the image coordinates.

The algorithm used in the DVP is based on the work of Toutin (1985, 1986). The approach is centred on a complex series of transformations and although it obviously involves the collinearity equations, it benefits also from theoretical work in celestial mechanism. The implementation on the DVP and the formulation of the real time loop will be described in papers by the software team from Laval University.

5. NEW DIRECTIONS FOR THE DVP

In addition to a SPOT version, DVP are working on other new products. A module for plane rectification is available and will soon be joined by data collection for aerial triangulation (Agnard and Gagnon 1991), DTMs, coordinate geometry and orthophoto computation. In addition to new developments, steady progress is being made in refining the basic product and the next release will include useful improvements to screen refresh, model set up, including compensation for radial lens distortation, and data collection. Equally, there is scope for synergy with Leica, since work in which the latter has been involved in the areas of hardware acceleration and automation (Cogan and Lutz 1990; Kölb et al. 1990, 1991; Greenfeld et al. 1991) may be adapted to the MS-DOS environemnt.

6. NEW LEICA PRODUCTS: SD2000 AND MAPIT

Two products have been launched recently have a role to play in the interface between remote sensing and GIS, the SD2000 workstation and the MAPIT software product for data acquisition.

6.1 SD2000 Photogrammetric Workstation and 3D Digitiser

The SD2000 (Fig.3) is a new analytical stereoplotter, the first from Leica (Cogan, Hinsken, Kolbusz and Walker 1991). It was launched at the 1991 ACSM-ASPRS Annual Convention in Baltimore. It combines, in a compact, aesthetically pleasing and very economical unit, the best features from the Kern and Wild lines, for example, the disposition of the stage plates one above the other as in the DSRs and the encoders and motor drive system from the BC3. The most important characterisitc, however, is the underlying principle of the photogrammetric workstation, whereby photogrammetric functions are localised in the workstation itself and coordinates are passed to, and commands received from, a host digital mapping system, CAD or GIS by means of a serial line. The letters in the instrument's name stand for "Stereo Digitiser" and highlight the role of the instrument as a 3D digitiser, a peripheral supplying three dimensional information to a host system. The controller is an 80386 PC and the software includes not only the real time loop and hardware diagnostic but also a new user interface, whereby almost all hardware functions, for example, illumination or size of measuring mark, are under software control. The design is not only comfortable and flexible in use, but contains minimal, modern electronics to ensure inexpensive, swift maintenance.

The communications protocols and libraries of the SD2000 are powerful but easy to use. As a result the instrument has already been successfully configured with a wide variety of host hardware, operating systems and software, so demonstrating its independence.

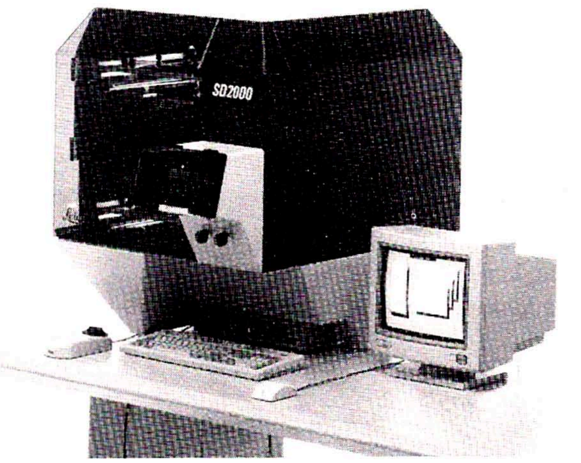

Fig. 3 - SD2000 analytical workstation and 3D digitiser.

In addition to Leica and Aviosoft products running under VMS, Unix and MS-DOS, the SD2000 has been successfully demonstrated with AMSA, KLT Atlas, DAT/EM, DDI CADMAP and KORK. The same principles are beeing carried forward to the superimposition under development, with tools to facilitate the transfer of superimposition versions of Leica and Aviosoft products from the DSR15 and BC3 and to provide an equally easy route for the third party vendors to implement superimposition in their own native environments.

6.2 MAPIT Software for Data Collection

A powerful connection is required between a photogrammetric workstation and a GIS/LIS system in order to avoid inefficiency or loss of data during transfer to the database. The operator wants to collect consistent data which are free of contradictions, but the necessary on-line consistency checks are time consuming and expensive, especially so when they take place on a photogrammetric workstation. One solution is fast data acquisition in a local data structure with strong consistency checks in a subsequent off-line step. Based on this idea, MAPIT (Fig.4) is Leica's new software for data collection with the DSR15 and SD2000. Using the database and data model of the LIS INFOCAM, it is the on-line interface between INFOCAM and photogrammetry.

MAPIT has four modules. In Collector, the photogrammetric operator gathers three dimensional data, "spaghetti" and points, in a local data structure. He assigns one or more thematic codes to each point or piece of spaghetti. He is free from structuring or descriptive tasks. The digitised data appears in real time on the screen and on the superimposition if fitted. Existing data from the database, menus and system messages are also displayed and superimposed.

After data capture, spaghetti are automatically structured by the Topology Builder. The result is a node-edge structure for use in INFOCAM. Objects such as regions or lines are assembled by comparing thematic codes. Geometric and thematic consistencies are then checked and irregularities recognised. Overshoots, undershoots and unclosed regions are automatically corrected if they fall within prescribed tolerances, which can be adjusted to the needs of each project. Larger irregularities are flegged for subsequent interactive correction within the Editor, the third module.

Once the geometry has been correctly generated, attributes are entered to complete the information for the database. The Editor also permits digitising, in structured mode, directly into the database with the consistency checks on-line.

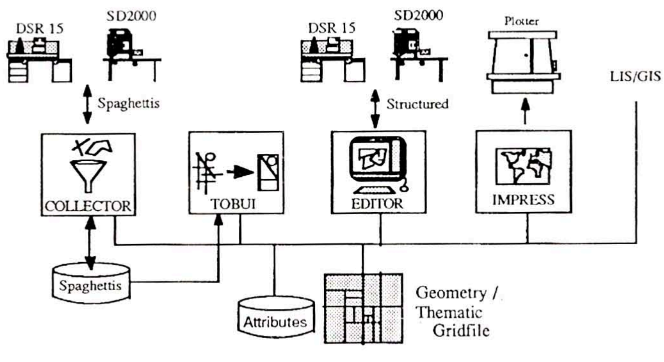

Fig. 4 - Schematic diagram of MAPIT.

The fourth module of MAPIT, Impress, is a program for interactive generation of layouts of high quality maps and plans including manipulation of legends, margins, titles, coordinate nets and diagrams. The main goal of MAPIT, however, is not only making attactive maps. The newly captured or updated data is in a database - INFOCAM. Data can also be imported or exported from or to other databases.

CONCLUSION

After some introductory material in Leica and its photogrammetric products, the DVP Digital Video Plotter has been presented. It evidently meets its objectives of providing a wide customer base with an economical digital photogrammetric station based on a standard PC. Further refinements and new models will certainly established the DVP as a most attractive product for data collection and revision by photogrammetrists and non- photogrammetrists alike. The price, the immminent launch of a SPOT module and the interfaces to popular CAD and GIS products ensure that the DVP will interest the remote sensing world. This commitment by Leica to data acquisition for CAD/GIS is further demonstrated by the recent products SD2000 and MAPIT.

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