DIGITAL PHOTOGRAMMETRIC STATIONS REVISITED

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Commission II, WG II/III

Key Words: Digital Stations, System Development, Design, Automation, Algorithms

Abstract: In the civilian market segment Digital Photogrammetric Stations are around for about one decade - as University-based solutions first, later as commercial products. In some countries the digital systems have already outnumbered the analytical plotters. This is an indication of the remarkable changes which digital technology has triggered even outside research laboratories. This paper provides for a critical review of the state-of-the-art of current Digital Stations. It comments on the achievements in system development and investigates to what extend the original expectations, demands and predictions have been fulfilled.

1. INTRODUCTION

The first commercial fully digital photogrammetric stereostation was presented as DSP1 by KERN & Co. AG at the XVIth ISPRS Congress of the ISPRS in Kyoto, 1988. It was wrapped into the PR-slogan „We yodel digitally - yodel with us". The yodel with DSP1 did not last very long. Problems with the provider of the integrated image processing system and the mere fact that the system came onto the market too early before the „toe of growth curve" (Helava, 1988) was reached, made it fail soon after. This system had a number of military- and University-based predecessors (Case, 1982, Albertz, Koenig, 1984, Gruen, 1986, 1989, Gugan, Dowman, 1986), so that as of today we can speak of roughly a decade of concrete civilian development of Digital Stations. This is the right time to critically review the achievements in system development and to investigate to which extend the original expectations, demands and predictions have been fulfilled.

This review does not aim at completeness, it will rather shed some spotlights onto individual system components. It will express the views of a University researcher and teacher, which are different from those of system manufacturers and users. Since the author was one of the earlier proponents of such systems and has done with his group throughout the years some research and development in this area, this review will be personal and biased.

As a general observation, the relation between system manufacturers and research groups has changed in recent years substantially, as far as their attitude and approach to innovative system and methodology development is concerned. At the time of analogue photogrammetry and the early years of analytical photogrammetry the system manufacturers were the driving forces. Through their in-house development of new instruments they provided the subjects for the research groups in such a way that researchers very often only could react and restricted themselves to testing and investigating the performance of these instruments. With the advent of digital technology the emphasis shifted in a twofold way. Firstly, creative new ideas for algorithmic solutions in digital data processing were required and secondly, through the use and integration of inexpensive off-the-shelf hardware components digital systems could be put together by virtually anybody with sufficient knowledge in digital photogrammetry. This led to the current situation where the software solutions of manufacturers are trailing far behind the state-of the-art of research. On the other side, many new system vendors have entered the market, not all of them proving that solid photogrammetric know-how in combination with competence in image analysis can be transformed into sophisticated and up-to-date solutions.

We have collected, in form of a table, information on 18 currently available commercial systems (excluding specific systems for close-range applications). These are more products than were available at any moment of time in the history of analogue and analytical stereoplotters. This might leave the impression that these are well developed systems for a commercially attractive market. We cannot argue about the latter, but the former definitely does not apply. Development in close-range and aerial photogrammetry is progressing along different tracks. Digital close-range photogrammetry has long gone fully digital and has majored to an extend such that almost fully automated, robust multi-image on-line solutions are being used in a variety of practical application fields (industrial metrology, bio-mechanics, animation, flow measurements, etc.). Digital aerial photogrammetry on the other hand is still severely struggling with automation, has analogue components in the chain (aerial photographs, printed orthophotos and map sheets), cannot quite separate itself from 2.5-D object representations, as opposed to moving to a fully 3-D approach, and is predominantly focussing on very traditional two-image processing concepts. As an explanation for this situation very often the higher complexity and larger format of aerial photographs is referred to. This is true to some extend. On the other hand the mapping community, which is still the driving customer force of digital systems, has never been overly innovative.

In this paper, we will exclude close-range systems, because they constitute their own class of digital systems, with application-specific requirements. We start with a brief survey of commercial photogrammetric systems. Then we will comment on some selected system components and major functions, like image scanning, user interface, image measurement/feature extraction, DTM generation, triangulation, orthoimage production, monoplotting, and automation in general.

Table1: Commercial digital photogrammetric systems (excl. close-range systems) - status February 1996

Vendor	Product	Computer	Operating system	Special Hardware	Stereo-viewing	User Iterface	Functionality	Year of Introd.[1]	Type of sensors[2]
Leica/ Helava	DPW 670, DPW 770	SUN	UNIX	Du Pont processor	Mono, Tektronix stereo	X/Motif	OR, AT, DTM, TIN, OP, DM, VI, OM, SCA, DAT	1994	frame, panoram., SPOT, Landsat
Leica/ Laval Univ.	DVP	PC	DOS PS/2		Split screen/ Stereoscope		OR, DM, AT, OP, DTM, TIN, MP	1989	frame, satellite
Intergraph	InterMap 6887 ImageSt.	Intergraph work-station	UNIX	VITec VI-50 image comp., (de)comp-ressor	Stereo-Graphics	X/Motif	OR, AT, DTM, TIN, OP, DM, VI, SCA, DAT, OM, IP, GIS	1992	frame, SPOT
Zeiss	Phodis ST	SGI	UNIX		Stereo-Graphics	X/Motif	OR, AT, DTM, TIN, OP, DM, DAT, SCA (MP, OM)[3]	1993	frame
I^2S DATRON	PRI^2SM	SUN, SGI, HP	UNIX		Mono, StereoGraph.	X/Motif	AT, OM, OP, DC, DM, DTM, IP, GO, OR, TIN, VI, GIS, RS	1990	frame, SPOT, SAR
Matra MS2i	Traster T10	SUN	UNIX	dedicated processors	Tektronix stereo	X/Motif	OR, DM, DTM, TIN, AT, VI, OP, GIS	1990	frame, satellite
ISM[4]	DIAP	PC	DOS UNIX		Stereo-Graphics		OR, AT, DTMm,TIN, OP, DM, VI, SCA	1992	frame
Vision Int'l[5]	Softplotter	SGI	UNIX		Stereo-Graphics	X/Motif	OR, AT, DTM, TIN, IP, OP, DM[6]	1994	frame, SPOT
Vision Int'l	Kork DMS Orthokork[7]	PC	Windows, Windows NT		Mono		DM, OP, OM	1994	frame
R-WEL, Inc.	DMS	PC	DOS		Anaglyph		OR, DTM, OP, DM, VI, RS	1987	frame, satellite
Galileo	Stereodigit	PC	UNIX		Dual monitor/ pass. polar. glasses		OR, DTMm, DM	1993	frame
	Orthomap	PC	UNIX		Mono		OP, MP, OM	1990	frame
DAT/EM	Digitus	Various	UNIX		Stereo-Graphics	X/Motif	OR, AT, OP DM	1993	frame
Topcon	PI-1000	PC	DOS		3D display, pol. glasses		OR, DTM, DM	1988	frame
VirtuoZo Inc.	VirtuoZo[8]	SGI	UNIX		StereoGr. Anaglyph	X/Motif	OR, DTM, OP, DM, TIN, VI	1992	frame, SPOT
INPHO	Var. S/W packages	SGI	UNIX		Mono	X/Motif	OR, DTM, TIN, GPS, DAT	1993	frame
PCI	Easi/Pace	Various	UNIX, DOS, Windows		Mono	X/Motif	OM, DM, DTM, OP, OR, GIS, RS, IP, VI	1991	frame, satellite , radar
Erdas/ Autometric	Orthomax	SUN, SGI	UNIX		Stereo-Graphics	X/Motif	AT, DM , DTM, TIN, OP, OR , IP, RS, raster GIS, VI	1992	frame, SPOT

[1] In some cases the products appeared in the market much later than when it was announced by the vendor. In other cases the full development of the product took several years. Thus, the year of introduction is an approximate indication.

[2] Satellite sensors refer in most of the systems to SPOT and Landsat.

[3] Options by using Phocus PM.

[4] International Systemap Corp.

[5] Vision International is the civilian part of Autometric Inc.

[6] Using the Kork DMS software.

[7] The system can make use of the TNT-MIPS GIS package of MicroImage Inc. for mosaicking etc.

[8] Product previously known as WuDAMS and mainly developed by Wuhan Technical University of Surveying and Mapping.

2. SURVEY OF COMMERCIAL SYSTEMS

Table 1 shows a summary of commercial photogrammetric systems. It was prepared in essence by Dr. E.P. Baltsavias. This account, although quite recent in nature (February 1996), does not claim completeness.

The following abbreviations are used in the Table to describe the functionality of the systems:

AT ...aerial
DAT ...digital aerial triangulation (semi-automated)
DC ...digital cartography
DM ...digital mapping. It includes feature acquisition and updating, attributing and in some cases plotting
DTM ...acquisition (manual or automatic) of DTM
DTMm ...only manual acquisition of DTM raw data
GIS ...GIS functions. Usually for analysis, combination and representation of raster data
GO ...geometric operations, coordinate measurement, image warp/registration
GPS ...aerial triangulation with GPS camera stations
IP ...image processing. Most systems have rudimentary image processing (LUTs, contrast enhancement, histogram transformations, geometric transformations), but some have a wider functionality
IS ...image sequence acquisition and analysis
MP ...monoplotting. Usually it refers to feature extraction and vector update using an image (typically an orthoimage) as a backdrop, without the use of the underlying DTM for determining the height
OM ...creation of orthoimage maps. It involves combination of raster and vector data and plotting of the orthoimage map
OP ...generation of orthoimages. In some cases it also includes mosaicking
OR ...orientations (interior, exterior)
RS ...remote sensing functions (typically multispectral classification)
SCA ...scanning of films by using a scanner of the same vendor
TIN ...interpolation of a regular DTM. Derivation of other products (contours, profiles, volumes) and their visualisation
VI ...visualisation. Typically it includes 3-D perspective views of the terrain (overlay of orthoimages on DTMs).

A closer look at these systems reveals that they are all more or less consequently designed after the „modular" concept, recommended by Gruen, 1989 and realized by our group as DIPS II in 1986 and in the years to follow (Gruen, Beyer, 1991). The computer platforms are either Unix-based (SUN or SGI workstations) or PC's. Special processor hardware is used only in a few (expensive) systems. Stereoviewing is predominantly through polarization and time multiplexing. The majority of systems has been introduced fairly recently (1992-1994). What this table does not show is a statistics on out-of-production commercial systems. Since 1988 we counted eleven such products, most of them equipped with special processing hardware. This is a clear indication of the fluctuations in this market. Currently, two major vendors hold a share of 75 % of the worldwide market. It will be difficult for other competitors to alter this relation, unless they can offer something more innovative, of higher functionality and automation, easier to use and less expensive.

3. COMPONENTS OF DIGITAL STATIONS

3.1 Image Scanning

Image scanners are offered nowadays at very different levels of functionality, performance and price. Baltsavias, Bill, 1994 give a good account of scanners suitable for photogrammetric applications. Scanners are currently probably the only area where Digital Stations-related scientific investigations are being conducted at a larger scale and with international participation, including equipment manufacturers (OEEPE/ISPRS Working Group on Scanner Test). It has been shown by Baltsavias, Waegli, 1996 that medium and low cost desktop scanners, if appropriately calibrated, can produce results almost as good in terms of geometric quality as the highend „photogrammetric" scanners, with partially superior radiometric quality. Another distinctive advantage of desktop scanners is the ease of use and the high scanning speed. This has to be weighted against restrictions in geometrical resolution and format. Currently flatbed desktop scanners cannot produce data with pixel sizes smaller than 21 microns. If, however, the development of general purpose scanners will turn out to be as dramatic as in the field of printers we may very soon witness a substantial improvement in resolution and a further drop in price with the result that specific „photogrammetric" scanners are not of interest any more. Scanners also should offer some local processing capabilities. Functions for image enhancement, editing, browsing, and image resampling are already available in form of public domain raster processing software. Also, interior orientation should already be established and performed automatically at the scanner level, before the data is transferred to the Digital Station (compare e.g. Leica/Helava DSW 200, Zeiss/Intergraph PS1). Finally, some level of on-line scanning control and local intelligence could be imagined, which allows to scan local image regions with varying geometrical resolution, either according to preset locations (e.g. for locally high resolution signalized object point regions), or even by online analysing the signal content of image regions and adaptively changing the resolution. These image data sets would of course also require particular storage and data handling techniques at the Digital Station. Another option would be to scan at very high resolution and to apply an adaptive compression technique which maintains the high image frequencies (e.g. signalized points) locally.

3.2 User Interface

In a largely automated system the user interface should not play a very significant role. Helava, 1988 remarks that „Digital image photogrammetric systems should be designed to be automation friendly". The current status of the user interfaces of the commercial systems is actually a strong indicator of the low level of automation. Buttons, menus, scroll bars and images are all over the place in most systems. It needs a real knowledgeable and experienced operator to navigate without failure and frustration through

the jungle of information. How can an external user learn to drive such a machine within a short time? Is that „poor man's photogrammetry", what some experts claim, usable by people taken virtually off the road?
At this point it is worthwhile to quote an experienced user of digital stereostations (Colomer, Colomina, 1994): „Individual intensive training for the operators used to the analytical stereoplotters takes two days. Afterwards, it takes two to three weeks until they become familiar with the stereoworkstation. During this adaptation period, the operators manipulate the system in quite an erratic way, causing the system to fail frequently."
We know of University professors exhibiting great pleasure in offering such a system to their students as a video game. Our children have surely deserved more exciting video games!

In all seriousness, it seems that user interfaces have grown on-the-job, out of the pressing necessity to present a system to customers. Maybe we are wrong, but we do not know of any scientific study dealing comprehensively with user interface issues on digital stations. We add a few observations in the following.

(a) Stereo display. The original excitement about the polarization display has recently led to some objections. Are we content with the loss in resolution through stereo interlacing? What about those disturbing reflections? Is the usual amount of ghosting really acceptable? Does the low transmission rate (around 30 percent) hamper our viewing comfort and quality? Could it be that having more than one person looking at the same time at the monitor is not so much of an advantage in daily production?
And finally: Is the intensive and tiring stereoviewing necessary at all, or could procedures be developed which need stereoviewing only in questionable cases to facilitate image interpretation? Thus stereoviewing should rather be seen as an add-on and switch-on capability and not as the basic most important feature.

(b) Number of monitors. While some people claim a one-monitor system is the right solution, others opt for two monitors, to separate image/model viewing and control functions. Personally, I am in favour of the one-monitor solution, which should however be freed from excessive button and menu displays and other redundant control elements.

(c) Subpixel image roaming. One of the major misdevelopments is the integration of special boards to allow real-time resampling with the goal of subpixel roaming. This is a very costly solution for a falsely defined problem. It originates in a conservative concept which intends to copy the analytical plotter functions one-to-one onto a digital station. Since analytical plotters allow to measure with an accuracy of 1-3 microns this is expected from a digital station as well. Thereby the most important capability of digital systems - to allow for automatic measurements - has been overlooked negligently. This is in strict contrast to the ideas and concepts put forward by the early advocates of digital stations (Case, 1982, Gruen, 1986, Helava, 1987, 1988). Helava actually remarks in Helava, 1988: „What does a digital image photogrammetric system that needs a human operator offer to make it superior to the conventional stereo instrument? The answer, at this time, has to be: Very little." In fact, one of the major advantages of digital stations has thus been ignored. The argument that automated measurements do not work does not apply here. We and others have proposed for quite some time that interpretation of the feature (on the lowest level: point, corner, edge) is done by the operator, while the computer is supposed to do only the fine measurement.

3.3 Image measurement; feature extraction

Image measurement or feature extraction has so far been one of the most neglected issues in Digital Stations. Commercial systems offer only the bare minimum. This consists in the provision of a point-type measuring mark, to be used in mono and stereo mode in pretty much the same way as on analytical plotters. Much of the latest achievements and findings in computer vision and digital photogrammetry with respect to model based measurement concepts and automation in feature extraction seems to have gone unnoticed by the system manufacturers.

Feature extraction is a major topic today in the computer vision literature. Besides, quite some progress has also been reported in photogrammetry with the precise and semi-automated extraction of points and edges in close-range applications (Beyer, 1992, Gruen, Stallmann, 1991). Some of these techniques have already been transferred to aerial images (Kersten, Stallmann, 1995) and algorithmically further developed into sophisticated approaches for linear feature extraction, using dynamic programming (Gruen, Li, 1995), globally constrained least squares matching (Gruen, Agouris,1994) and LSB-Snakes (Gruen, Li, 1996). We claim that any low level feature which can be measured very precisely at subpixel level at all, can be measured automatically. If a local signal is so weak or distorted that a precise measurement is not possible, subpixel resampling and roaming does not help either. Automated measurement can be done with a catalogue of templates, whereby the operator chooses the appropriate template and pulls it manually to the approximate location. Templates can be generated for a great variety of different features. They may consist of synthetic or real greyvalue image patches or they could represent the absolute values of the first derivatives of the greyvalues. The latter keeps the template independent of greyvalue inversion, such that light/dark and dark/light edge transitions can be treated with just one template (Baltsavias, Stallmann, 1992).

Template matching can be considered an elementary form of model-based extraction. When forming or selecting a template one uses a model of the feature of interest. The template constitutes the 2-D projection of the object model into the image space.

All the previously addressed approaches assume that the object is either locally plane or a space curve. More complex and truly 3-D surface based object extraction techniques have also already been proposed and used for

model-based measurement both in close-range (Chapman et al., 1992, Streilein, 1994, Li, Zhou, 1994) and aerial (Quam, Strat, 1991, Lang, Schickler, 1993) applications.
A first step into the right direction is realized in the PhotoModeler system (http://www.photomodeler.com.), where a coarse CAD-model of the object is used to determine interactively the approximate values for the exterior orientation of the images. This is achieved by backprojection of the wireframe model of the object into the images and by operator-guided matching of the model projection and the respective image features.
At the next level, the measured feature primitives have to be structured into 2-D or 3-D objects for further use in CAD systems and GIS. This structuring also needs support from automation, because manual procedures are very time-consuming. Very little is known about related functions on Digital Stations.

3.4 DTM generation

The problem of image matching for precise and reliable DTM generation is not solved yet. This holds for academic approaches and even more for commercial software. Occasionally users of automated DTM generation software remark that the „results are not very good, but acceptable for orthoimage production." This is a comment born out of frustration rather than a convincing argument. In the past, DTMs have been created to such a level of quality that they could be used for many different purposes. Actually, among all geo-related data sets a DTM was considered the most permanent and reusable set over time. Are we satisfied nowadays in producing „throwaway DTMs", just good for orthoimage production at a particular scale? Can we accept DTMs which cannot produce „good looking contours" and which deliver, if at all, output statistics which „are not helpful enough" (Torre, 1996).
In brief the major problems with automated DTM generation software are:

- Recognition and measurement of object edges and geomorphologically important features
- Bridging of regions with poor signal content
- Handling of occlusions and shadow areas
- Reduction of a Digital Surface Model (DSM) to a Digital Terrain Model (DTM); this includes recognition of trees, bushes, buildings, etc.
- Quality assessment; internal quality control (blunder detection and location)

We have tested commercial DTM software (Leica/Helava DPW 770, Virtuo Zo) on various projects under varying conditions. Detailed reports can be found in Brossard, 1994, Baltsavias et al., 1996. Without manual editing, the results were not convincing.

In summary it must be noted that to achieve good quality results which are equivalent to operator measurements, a substantial amount of editing is necessary. We believe, however, that there are concrete possibilities to improve the results. One is to use a multi-image approach, as emphasized in the following. The other is to use color and texture measures for tree, bush and building detection and separation (Henricsson et al., 1996). Thus the purely geometrically based reconstruction procedures could be supported by image understanding algorithms, which are currently investigated at various research labs.

Since DTM generation is basically an ill-posed problem, a remedy cannot consist in producing a great number of points for which no reliable quality measures are available. At least the problem of reliability could be tackled by using more than two images in the matching procedure. This multi-image mode has been suggested as early as in Gruen, 1985a and the first results of this approach have been presented in Gruen, Baltsavias, 1986. Recent investigations with a modified version of this concept confirm the good performance (Maas, 1996).The multi-image mode improves precision and especially reliability significantly. Depending on the number of images used simultaneously in matching, the number of blunders can be reduced dramatically. Also, occlusions can be handled very well with this approach.

3.5 Triangulation

Many optimistic statements have been given recently by the user community concerning the advantages of digital and (semi-) automated triangulation. Semi-automated triangulation seems to be fairly well advanced in at least two major vendors' systems. This is not so surprising considering the fact that already in 1987 the DCCS had offered an apparently operational software (Helava, 1987).

(a) Early investigations (Ackermann, Schneider, 1986) have shown that the results of digital triangulation are of the same accuracy as those of the triangulation with analytical plotters. Considering the latest findings on the very high accuracy of image measurement of signalized, well-defined points, the digital triangulation results should be even significantly better. The reason that this could not be confirmed in empirical tests so far has its origin primarily in errors introduced through image scanning. Recently we have shown that with direct digital image acquisition using a Kodak DCS 200 still video camera, the planimetric accuracy can be improved by roughly a factor two to 1 micron in image space (Kersten, 1996). However, with 0.1 ‰ flying height the height accuracy is by a factor three well below the performance of an aerial photographic camera. This is partly due to the narrow bundle of rays of the video camera (18 mm camera constant at a CCD chip format of 14 mm x 9.3 mm).
At this point it seems worthless to conduct accuracy tests in digital triangulation based on natural object points and on significantly distorted images by scanning. Scanning errors can be better checked and isolated otherwise (Baltsavias, Waegli, 1996), without going through a full block triangulation procedure. Furthermore, for the test of a system's accuracy capability, signalized well-defined points should be used.
(b) Another problem worth mentioning is that of an appropriate pixel size for triangulation. If triangulation is done with only natural points (control points, tie points, new points) requirements concerning pixel size are fairly relaxed and depend on the type of object point and on the image scale. A pixel size between 20 and 40 microns should usually suffice. If, for high

precision applications, signalized points have to be measured, the pixel size has to be derived from the requirement that the minimum target diameter in image space should be four to five pixels. Five pixels at 10 micron would result in an image diameter of 50 micron. Therefore, what can be considered an optimal size for analytical triangulation constitutes the bare minimum for digital triangulation. This has to be carefully considered when object target size, image scale and scan pixel size are selected. Depending on the image scale and scan pixel size digital triangulation may require very large and inconvenient signals on the ground.

(c) A third issue to be addressed is the fact that commercial triangulation systems by and large are still following even the analogue photogrammetry concept. Blocks are built up through measurements in strip direction, collecting image data from one strip after the other. Bundle adjustment is performed in batch mode only after all images have been measured. This procedure ignores the fact that blunder detection can be performed much better on-line if the images are measured according to the avalanche principle out of a particular block corner, building up highly reliable units very quickly (Gruen, 1983). The possibility of displaying a set of six or even more conjugate image regions greatly facilitates this measurement concept (compared to the corresponding procedure on analytical plotters). Such on-line control of measured data should be supported by the appropriate computational strategy. For that, suitable sequential estimation algorithms are available for on-line bundle triangulation for quite some time (e.g. Gruen, 1985b, Kersten et al., 1992). To be able to detect even small blunders not very far above the noise level, additional parameters for systematic error compensation should be included in the sequential estimation.

(d) On the positive side we note that semi-automatic triangulation, even with current commercial technology, allows to measure many more tie points than conventionally, in much shorter time. Practitioners report about 35-40 aerial images being measured in half a day. However, this does not include the time for scanning, preprocessing (minification, compression) and data handling. These procedures (1,5 hours per photograph have been reported) slow down the gross time substantially. Also, if the disk cannot accommodate the image data for a full block, data transfer time and thus the overall triangulation time will increase tremendously.

3.6 Orthoimages, orthomaps

It is generally acknowledged that orthoimages are the first (and so far only (?)) practically requested products from Digital Stations. Once a DTM is available, the process of orthophoto production is straightforward and could be implemented on a desktop computer. Also, the supporting software like image enhancement, mosaicking, etc. is fairly standard today, as are map annotation programs. Therefore, under these conditions, it is somehow amazing that users invest a lot of money into highend Digital Stations with all their redundant functionality, just for the purpose of orthoimage generation.

Orthoimages are correct representations, if the object is sufficiently smooth. Since buildings and other man-made objects are usually not well modelled in DTMs/DSMs the locations of roofs, etc. are false. Roof correction software has so far been offered by only one vendor (Leica/Helava), although the correction algorithm and its implementation does not pose any serious problems (Dan, 1996).

3.7 Monoplotting

As DTMs and DSMs are becoming increasingly available the issue of monoplotting deserves much more attention. Monoplotting is fast, easy to perform and does neither require bulky and expensive stereo display nor highly skilled stereo operators. However, monoplotting is only as accurate as the underlying DSM. This will restrict it to certain classes of application, of which there could be plenty around.

Image matching supported monoplotting is another capable mode for feature and object extraction. While the operator positions the cursor in just one image on the feature of interest the matching is performed, preferably in a multi-image mode, in the background and on-line. A first rudimentary solution of this kind can be observed on Vision International's Softplotter.

3.8 Automation in general

The current level of automation on digital stations is fairly low. The production of an orthoimage, given a digital image, its orientation and a DTM, cannot figure under „automation“. We see first reluctant steps towards automation in the following areas and on some few stations only:

(a) Interior orientation. Should work in general. Works in some cases.
(b) Relative orientation. Is offered on some systems. Has not shown to work safely under general conditions.
(c) Absolute orientation. Control points, no matter if natural or signalized points, have still to be measured manually.
(d) Triangulation. Tie point measurement is reported to work largely automatically, but even in a major system an error rate of 30% is reported. Control points and new points have to be measured manually.
(e) DTM generation. Fully automated solutions are offered, but results need much editing.
(f) Feature extraction, mapping. One of the most important functions. Automation does virtually not exist.

In summary, what is unsually called „automation“ has to be put into the right perspective. There is no reliable black box in photogrammetry. Many algorithms which are called „automatic“ might work without operator interference, but they usually require some, often many, parameters to be set in advance. The results will then heavily depend on this parameter selection. This is the point where either photogrammetric expertise or longstanding project experience has to enter the picture. Correctly, Colomer, Colomina, 1994 remark: „Furthermore, (semi-) automatic software uses parameters for tuning results to different types of projects. Although manufacturers provide default values for these parameters and some hints on how to use them, one must try to achieve a deep knowledge of their behaviour with intensive testing by production staff and application specialists with knowledge of the theoretical foundations of the algorithms." Needless to say that the theoretical foundations of implemented algorithms are not always released by the system developers and manufacturers. Compare also the remarks about DTM strategy selection in Baltsavias et al., 1996.

4. CONCLUSIONS

In the early years of digital system development a number of criteria were formulated to express potential advantages of digital systems compared to analytical plotters:

(1) Increased accuracy
(2) Reduced equipment cost
(3) Increased througput (automation)
(4) Less qualified operators (simple user interface, no or little stereoviewing)
(5) Faster availability of results (on-line and real-time processing)
(6) Fast image transmission (use of digital images)
(7) Better quality and more flexible products (combined, hybrid data)
(8) Better data integration; joint platforms with CAD/GIS
(9) New type of products (image based, visualization, animation)

While many of these potential advantages have been realized in close-range systems and applications, the commercially available systems for aerial photogrammetry and satellite remote sensing still have plenty of room for improvement. This is a great motivation for scientists and a comfort for developers. They both will not run out of work in the foreseeable future. And as developers are still battling with the realization of promises yet unfulfilled, new technolgies, requirements and expectations are rising at the functionality horizon of digital systems. At larger production sites the issues of system and component integration and of logistics become really pressing (Colomer, 1996). Multimedia technology could provide for new perspectives for the mostly awkward user interface solutions.

With the ever increasing availability of digital data, in particular image data, it will become more and more difficult and demanding to manage flow, storage, accessibility and retrieval of this information. Content-based image storage and retrieval techniques have already found wide interest in various areas of art, science and economy (Computer, 1995). Photogrammetry and remote sensing have yet to cope with it. Database issues are not only of relevance with respect to the CAD/GIS connection, but they inherently have to be addressed when dealing with digital depositories for both vector and image (pixel) data, which have to be set up as combined spatial and radiometric information systems.

We note that the system design and functionality issue of Digital Stations has somehow been neglected by the scientific community. As of today we have no comprehensive critical and comparative investigations available. This leads to the problem that the practitioners have not much competent support in terms of evaluating systems and setting up benchmark tests. Experiences are gathered with purchase decisions already made and systems in place.

In summary, we observe that the prediction, that the introduction of digital systems „radically alters the instrumentation and procedures employed, the personnel and clientele involved and the products generated" (Derenyi, 1995) could not be verified for the mapping community until today. We rather note a smooth transition from analytical to digital, with both systems still in use in parallel for a number of years to come. We realize however one significant change. This concerns the attitude of students towards photogrammetry in general. Digital cameras, systems, processing techniques, and visualization tools proliferate so much fascination that it does not require too much extra motivation to attract the young generation to this discipline. And this is necessary today even more than before, if we consider the wise and far-sighted words of Paul Rosenberg, which he coined long before this generation was even born: „The engineering problems in electronic photogrammetry are very considerable ... It will be a long time before completely automatic, electronic photogrammetry is actually at hand" (Rosenberg, 1955).

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