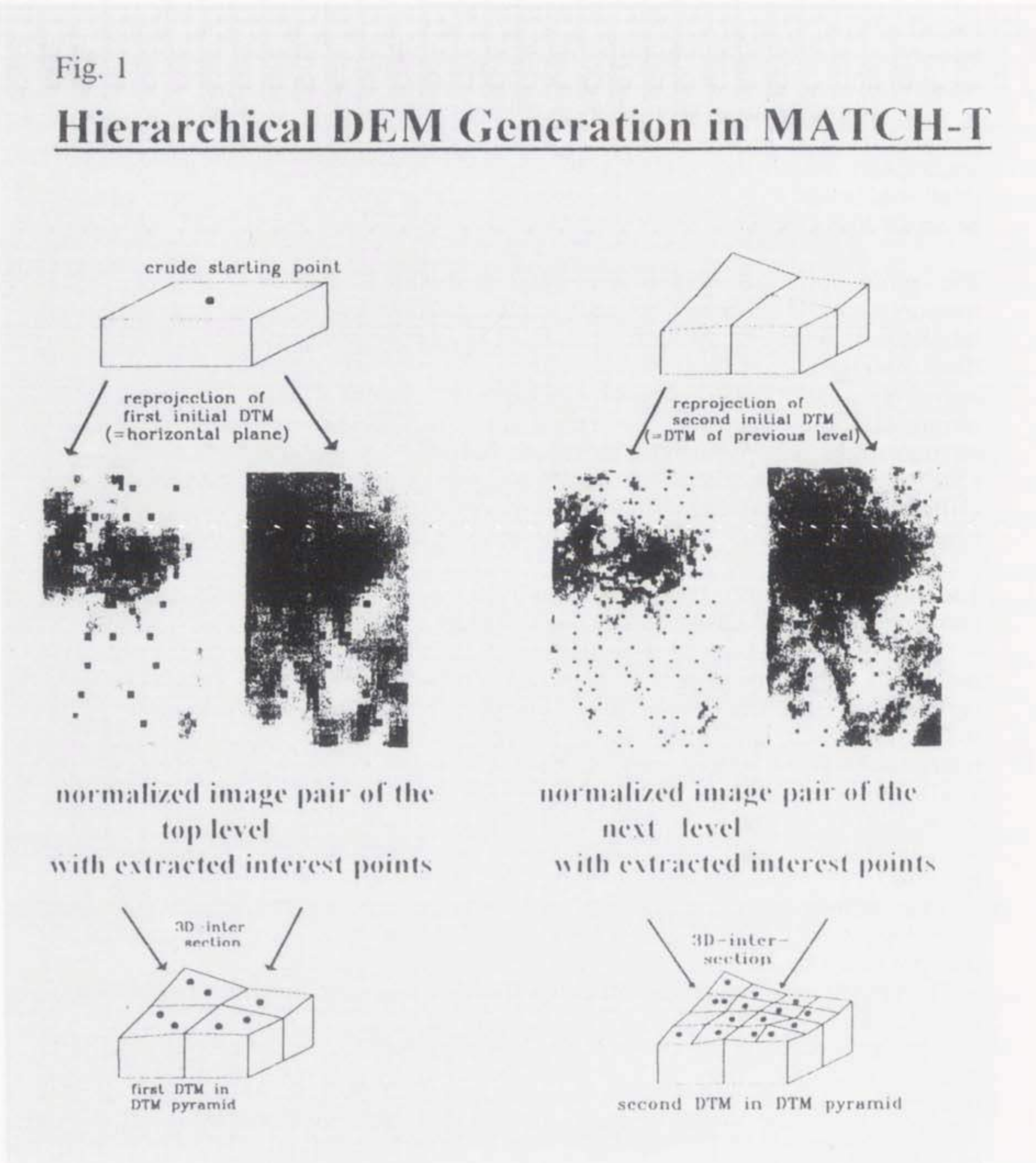

Fig. 1 Hierarchieal DEM Generation in MATCH-T

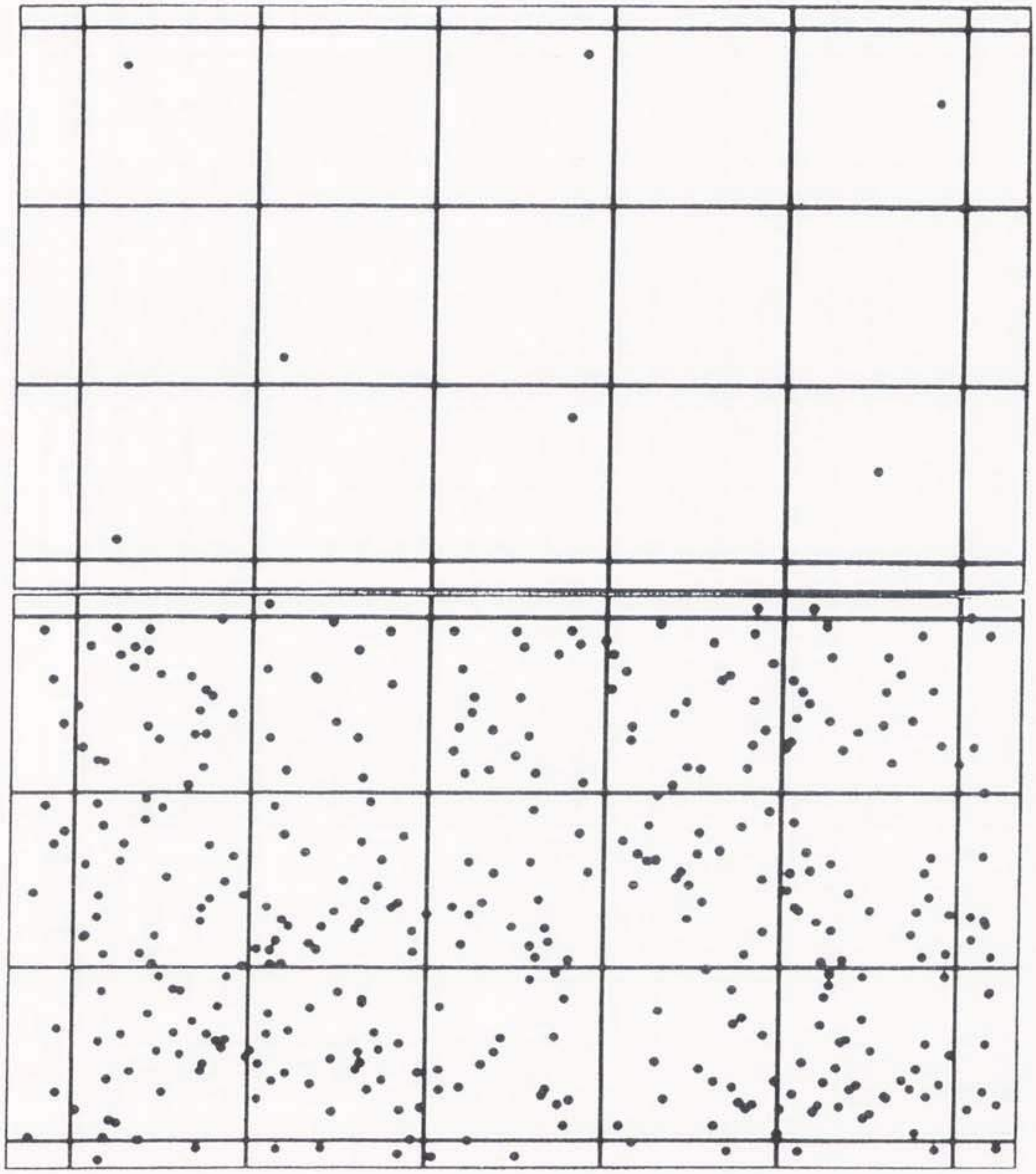

Fig. 2 Sparse (conventional) versus redundant (automatic) DTM data capture

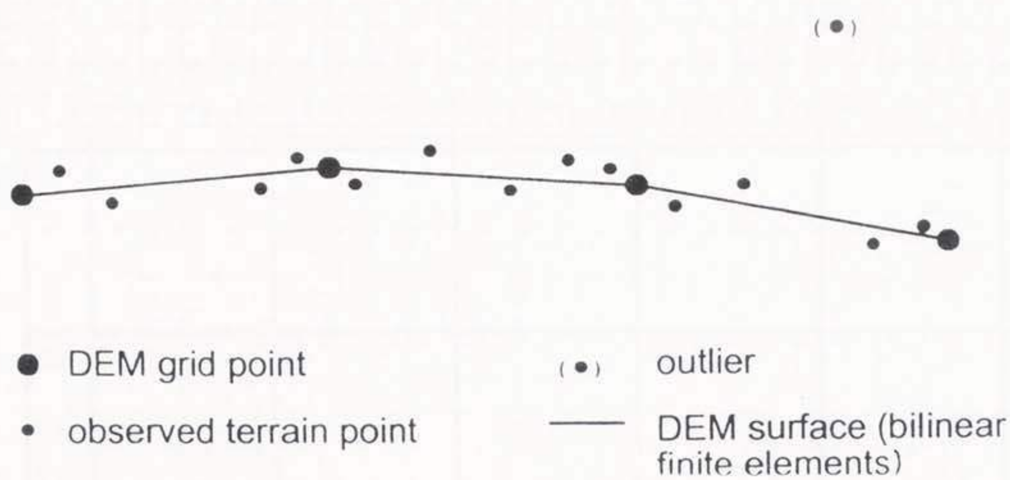

Fig. 3 Effects of redundancy

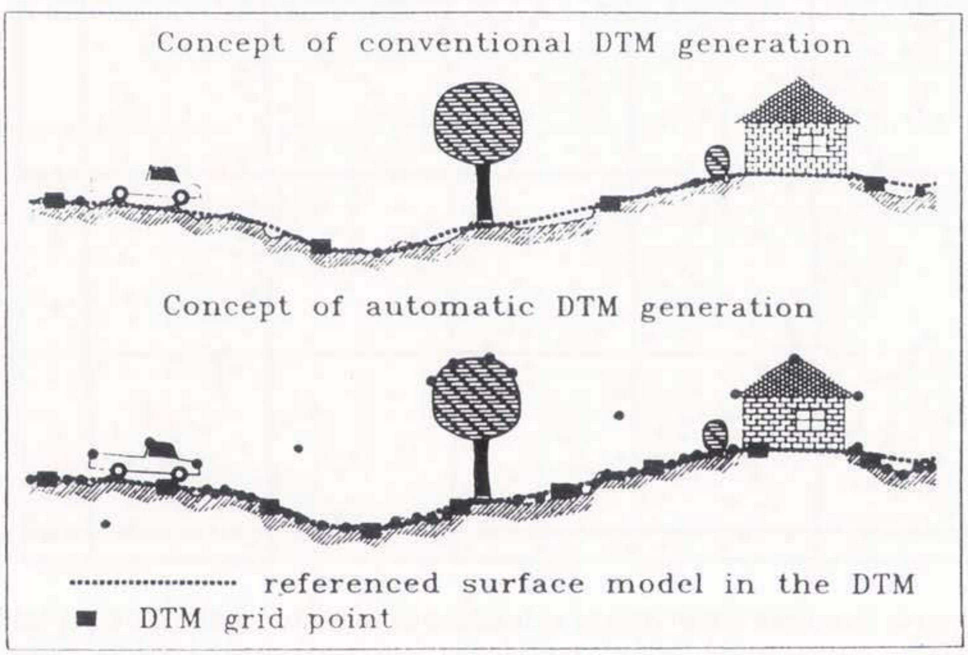

Fig. 4 The problem of terrain obstruction

2.4 A permanent point of discussion is the question of image **data compression**. When considering only pairs of images data compression may not be too important, but it is a question of general importance and it is regularly applied in many cases. Various investigations have confirmed that the JPEG compression up to linear compression factors of at least 5 have practically no deteriorating effect on the DTM accuracy. It must be kept in mind, however, that this statement concerns the global accuracy of the DTM. Local high contrast features may still be affected (i.e.shifted) by data compression.

2.5 Another question concerns the appropriate **pixel size** for DTM derivation. This is not discussed here in detail. It can be summarized, however, that experience and tests have confirmed that the DTM accuracy depends to some extent on the pixel size, but not in proportional ratio. In practice pixel sizes between 15 and 30 µm are acceptable, still allowing DTM generation of high accuracy.

2.6 The principle of redundant observations, by measuring up to 10^6 points or even more per stereo–pair, can be applied on condition only that the program operates fast enough. Actually, the **batch computing time** for MATCH–T, as described, remains in the order of **1 hour** or less, per stereo–pair, see (Ackermann, Krzystek 1995). It seems fast enough as the remaining interactive editing often takes longer (see below).

3. PROBLEMS AND LIMITATIONS

3.1 The practical application of automatic DTM generation can meet **difficult cases**. They occur in relation with certain terrain characteristics. A first problem can arise if the terrain resp. the images have quite **featureless** local **areas** with very **poor texture**. In such cases the extraction of feature points as well as area matching can fail. There is no general theoretical solution to the problem. Instead, the DTM programs try to get some result by parameter manipulation, by a variation of the standard procedures. The MATCH–T program, for instance, in that case switches to a denser search pattern for points, changes the threshold values and tries area matching as well. The program also may go back to the previous (higher) level of the image pyramid. It is understood, of course, that the program issues a DTM in any case, as the minimum principle of the finite element fitting provides a solution even if no or very few points are captured locally. Of course, such areas are flagged out by the program, for final **control and editing** by the operator and, possibly, additional interactive measurements.

A similar problem can occur in cases of extreme photographic **density range** when the (linear) 8 bit radiometric resolution of the scanned image does not sufficiently cover the total radiometric range of the image. Such cases of very dark and very bright areas can happen in images of open cast mines, or of large construction sites. If a non–linear histogram transformation cannot solve the problem the processing should be based on a 10 bit resolution which some new scanners can provide.

3.2 More serious is the **problem of obstruction**, if the imaged surface is not the terrain surface which the DTM is to describe, see Fig.4. That problem is of a principal nature and cannot really be solved by image processing methods alone. Unfortunately the case happens quite often, that vegetation or buildings cover the real or the fictitious terrain surface which itself is only partly visible or not at all. In such cases some or most of the matched points do not represent the real terrain surface and cannot be used for the DTM generation.

There are a number of **remedies** which can be taken in order to get reasonable results in such cases. For instance points on bushes, trees, or houses can be identified as **outliers** and automatically **removed**. That principle could be extended to cases where the majority of points need rejection (by looking for the lowest enveloping surface). In general, the obstacle problem is shifted to **interactive** control and **editing**. The operator would control the automatic outlier removal and would check which additional points are to be deleted or changed. He also would try and add **interactive measure ments** in order to obtain a satisfactory result. He also would define (preferably in advance) which areas would be excluded from the DTM capture. It could be closed wooded areas, densely built up areas, but also water bodies. The interactive editing – even if supported by sophisticated editing functions – can, in bad cases, be quite time consuming and might not sustain much advantage over the conventional analytical operator methods.

3.3 The obstruction problem can become particularly serious in **large scale, high precision DTMs**. Large scale DTMs are no problem, as such, if the terrain is open and the surface visible, even if high accuracy is asked. Often, however, large scale DTMs are wanted for detailed planning purposes, road construction etc. and thence may refer to built–up areas or suburbs with houses, gardens, trees, bushes which prevent visibility and direct capture of the wanted terrain surface. There is no direct automatic solution to such cases, recourse must be taken to extended **interactive editing**. Nevertheless, but for exceptional cases, automatic processing still seems to be advantageous, by speeding up the necessary interactive editing.

Nevertheless, it has to be admitted that there are cases and conditions where the automatic DTM generation more or less fails. It happens in particular in densely built up **city areas**, where constructions and tall buildings shadow off too much of the terrain surface. In such cases even interactive editing may not be really successful, unless multiple photo coverage can provide the necessary additional views. **Multiple image data** constitute, by the way, a basic advantage of digital photogrammetry systems to be exploited in future.

The concept of **DTM in city areas** has recently been given a reversed meaning, in so far as the buildings are not to be removed from the DTM but, instead, form part of a real **3 D model**. Hence, the buildings are to be captured as well. The conventional DTM approaches, based on smooth terrain surfaces, are not sufficiently capable of handling such cases. New, generalized matching methods and appropriate 3 D modelling need to be developed and applied.

3.4 It has been touched several times that the automatic DTM generation needs **quality control** and **editing** by an operator, after the automated processes have done their job. The actual automatic DTM generation runs in batch mode. But there remains the basic necessity for interactive quality control and, possibly, additional measurements. Hence, interactive editing is a **constitutional part** of any automatic DTM system. The necessary editing may be minor in many cases, but must not be skipped over. Therefore, the digital DEM generation is normally done in combination with a stereo–image station. Of course, interactive editing is supported as much as possible by editing functions provided by the digital system. Whether the present state of affairs is considered satisfactory depends on the demands and specifications of the actual applications. All systems make continuous efforts to improve and support the editing part as much as possible, as the demands are increasing.

4. CONCLUSION, STATE OF THE ART

4.1 Automatic DEM generation is certainly a **highly developed tool** of digital photogrammetry. In a majority of cases it serves its purpose very well, with clear accuracy and economy advantages over conventional analytical DTM generation. Together with interactive editing a high rate of success is achieved, and **different applications** are becoming served regularly. The main direct application of DTM concern the orthophoto production (which is the easiest case). Also national DEM grids as topographic data bases are a standard task, as well as DTM layers in any GIS data base, providing basic information for the solution of multiple tasks and their georeferenced presentation. A particularly important application concerns large scale high precision DTMs for planning purposes af various kinds.

The systems on the market operate with different approaches and different ways of obtaining results. Also different degrees of interaction are noticed. Nevertheless, all have the basic problem that the automatic DTM generation from aerial photographs has the **basic limitation** of the vegetation and other cover of the terrain surface. At present the problem is circumvented as much as possible by interactive editing, including support by extended editing functions.

4.2 The vegetation and obstacle problem cannot be overcome by image processing techniques alone, in case the above discussed remedies are not effective enough. A **multi–sensor** approach is considered the only feasible solution to the problem. Airborne laser scans are capable of penetrating through vegetation cover. Hence, a combination of **laser scanning** and digital image matching may constitute an effective **generalized approach** to the automatic generation of digital elevation models.

A generalized approach is also required for the problem of **3 D modelling** of city areas with tall buildings and complex engineering constructions. The necessary extensions will have to deal with multi-sensor data, generalized automatic matching methods (including edges) and genuine 3 D modelling. The extended problems raise new questions of a basic nature. Hence, for the time being, they are given back to the academic world with the appeal to come up with generalized methods and powerful **integrated solutions**.

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Automatic Derivation of a DTM with the Helava System

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Summary

The image correlation is the basis for the automatic derivation of digital terrain models, for the automatic generation of orthophotos as well as for the automation of aerial triangulation. One of the research topics which were carried out at the Institute of Photogrammetry was the accuracy analysis of the automatic terrain measurement by using the DPW Helava software. The paper gives an overview on the results of these tests.

1. Introduction

Image correlation plays a key role in the automation of the photogrammetric working process. The automatic correlation is a process of digital photogrammetry used to generate digital terrain models (DTMs) from digitized aerial photographs. A DTM is a description of the terrain shape by means of a set of topographical points and of an interpolation method used to calculate a mathematical surface. To achieve a greater precision, DTMs have to include structure elements, which are distinctive terrain discontinuities.

The image correlation and the automatic derivation of a DTM can also be used as starting point for the generation of digital orthophotos, which should play a key role for a number of planning activities in the near future. Furthermore, digital orthophotos are increasingly being used in geo-information systems (GIS). If one underlays the vector information on the monitor of a GIS with an orthophoto, then most of the photogrammetric plotting operations can be done directly on the working station.

In the last few years, a number of research groups have concentrated their efforts on the image correlation and on the automatic derivation of DTMs. At the Institute of Photogrammetry of the EPF-Lausanne, a small group has been heavily engaged for some years in the problem of image correlation and automatic derivation of DTMs. One of the research subjects which have been carried out at the Institute of Photogrammetry was the accuracy analysis of the automatic terrain measurement with the DPW Helava software.

2. The DPW workstation of Helava

The DPW Helava workstation used at the Institute of Photogrammetry is one of the most up-to-date and comprehensive workstations in digital photogrammetry. The software package allows to make (on the basis of digital aerial photographs or other digital images) maps, orthophotomaps, photomosaics, digital terrain models, 3D-images and vector databases.

The Helava workstation also allows the conversion of digital images and their interpretation. As it can communicate with a lot of GIS databases, the Helava workstation can supply the necessary data for engineering projects, spatial compositions and animation. But one of the main tasks which can be done by the DPW is the automatic creation of digital terrain models.

The algorithm used by the Helava software, allows the automatic measurement of a DTM from original (only oriented) digital photographs. This process does not require any further digital modification of the images, like for example, resampling. Thanks to this new ability of the software package for image correlation, it is possible to considerably shorten the (technological) process of data collection and to also reduce hardware requirements, like for example, the disk capacity.

New strategies of digital terrain measuring allow to increase the accuracy of measuring the relief itself, thanks to the implementation of filter operations in order to correct single trees or houses which would deteriorate the effective relief surface. They also allow automatic relief measuring with preservation of some of the relief characteristics like the steep of the slopes and the density of the measuring network.

The software of DPW Helava allows to give a quick and very precise definition of a three-dimensional terrain model. The measuring speed depends on the terrain configuration and on the quality of the digital photographs and oscillates in practice between 50 and 200 points per second. To measure a whole digital terrain model, an operator can define one or several separate areas for the correlation process which operates under the direction of one or several independent measuring strategies. There is also a possibility of increasing the measurement accuracy by using different measuring strategies for the same area.

In the DPW Helava, the output product of the image automatic correlation is a regular grid with a spacing defined by the operator. After having obtained a DTM, it is possible to display the result of the measurements as spatial points, profiles or spatial contour lines. At this stage, comparing a model configuration with the contour lines created from a DTM, the operator can make some necessary corrections (using all available editing functions) to the database which stores the automatic photographs correlation results.

The phase of the digital terrain model edition consists of two steps. The first is the automatic filtering of spatial objects, included into the strategy. The second is the interactive manual edition by the operator. It is worth pointing out that the operator does not have to make the editing point by point but that the software allows him to make the editing work for a whole batch or object.

At this stage, it is possible to define new data for a DTM, like for example, structure lines and the smoothing degree. After finishing the editing phase, all results (vectors and points) of a digital model obtained by automatic measurement can be extracted in various formats available for GIS databases and other software packages designed to create DTMs.

3. Accuracy analysis of the automatic derivation of a DTM with the DPW

One of the research topics which were carried out at the Institute of Photogrammetry was the accuracy analysis of the automatic terrain measurement by using the DPW Helava software. Two digital areas - La Broye and Kandertal - were used as comparative material for analysis purposes.

3.1 La Broye model

The model La Broye was measured on the analytical plotter Wild BC1 and consisted of four zones of measurement with a point spacing of 10m and a denser grid in the urban areas with a point spacing of 5m. Both black and white photographs were scanned in a 10 µm resolution on the DSW 200 which is dedicated for the DPW Helava.

The orientation process for La Broye was made by using triangulation points and the DPW software HATS, designed for orientation and aerial triangulation. The absolute orientation of the model was completed with $p_{xy}=\pm5$cm and $p_z=\pm7$cm.

Model La Broye - photograph showing the 11 different zones used for precision analysis of DPW Helava correlation

The next phase of the study was to project the comparative terrain model taken from the BC1 into the DPW Helava workstation. This move allowed the precise definition of control areas on the DPW Helava for the accuracy analysis of the automatic model measurements. Control areas were mostly defined on empty terrain surface, on which the measurements are not influenced by spatial objects as, for example, houses or groups of trees.

In the comparative DTM taken from the BC1, this kind of objects were defined as obscure areas. In each comparative zone, a few control areas were defined considering the various terrain configurations of the comparative model. While doing the measurements of the DTM, one or several co-strategies of measurements were defined, considering the comparative model terrain configuration.

This work flow schema allowed to calculate the accuracy of the terrain automatic measurements and to calculate the usefulness of each type of strategy, or their sequences for each type of terrain. In each control area, a regular network of measurement points were created, in which the distance between points was the same as in the BC1 network.

After creating the DTM for all control zones, the accuracy analysis was started. It is the original Helava software, which allows to analyze the divergence between two overlapping DTMs, which was used for this purpose. This software projected the DTM created by the DPW Helava onto the comparative DTM and calculated the minimum and maximum differences between the two models, the average distance between them and the mean observation error.

La Broye - results of the precision analysis of the Helava correlation
(flight height 900 m, picture scale 1:6'000)

Zone	Control points	Strategy	σ(H)
1	191	flat.strat*	± 6cm
2	553		± 6cm
3	144		± 7cm
4	477		± 5cm
5	90		± 6cm
6	320		± 9cm
7	93		± 7cm
8	232		± 8cm
9	466		± 8cm
10	874		± 7cm
11	195		± 9cm

* flat.strat: this strategy is used for flat or very small x-parallax stereo models. The criterion for maximum slope is set low (20 degrees) and spikes are also detected a low threshholds. This strategy will tend to «cut » through small trees and houses and will not model anything steep.

The original Helava software for analyzing a DTM does not give many possibilities of viewing the differences between DTMs; for example, it is not possible to look at the deviation on each measurement point. To study more thoroughly comparative and control model differences, they were moved to the Intergraph system, where further accuracy analysis was taken using the Modeler software package. This software made it possible to determine the divergence for each measurement point between two digital terrain models and could also calculate once again the average, minimum and maximum differences between them.

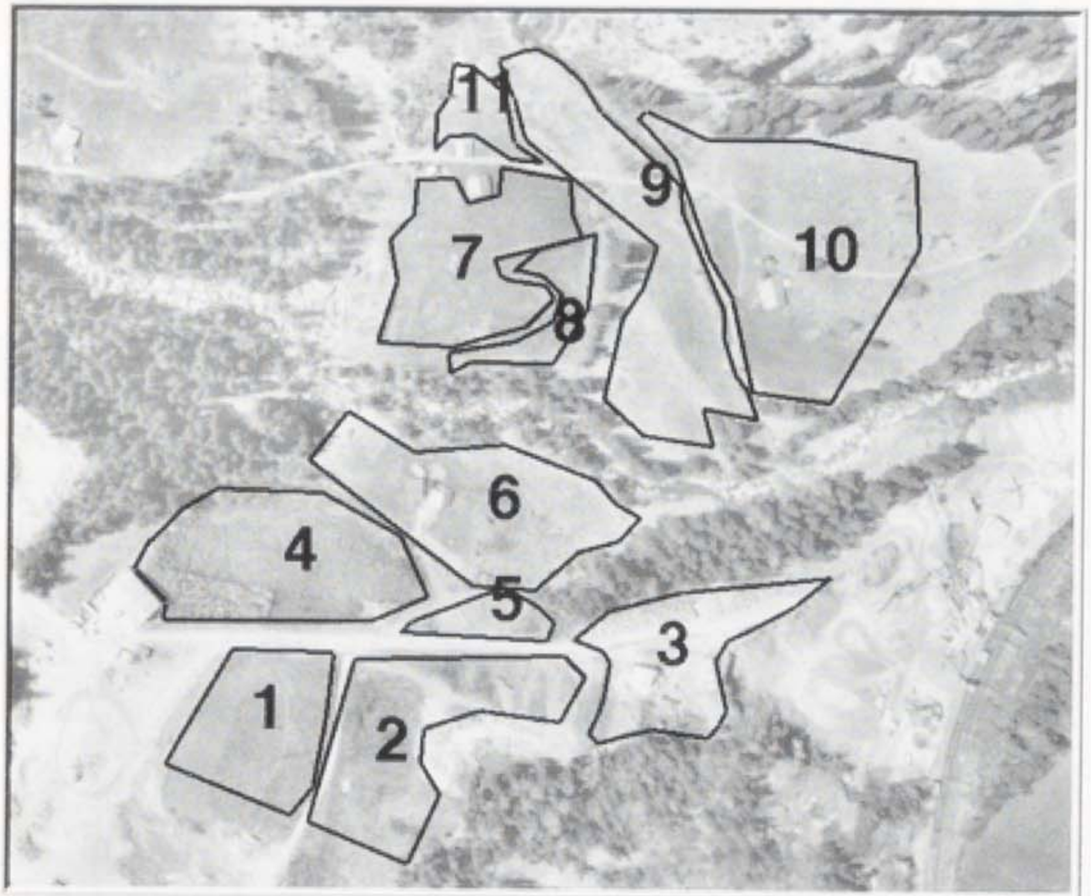
Thanks to the possibility of co-operating with the CAD system, this package allowed for the graphic presentation of the results.

3.2 Kandertal model

The second model - Kandertal - which was used during the test was much more difficult to create by using the automatic measurement of a DTM. The test region, which was previously measured on the analytical plotter, had a very different relief than the La Broye model. La Broye mostly consisted of flat regions separated only by roads or rows of trees. The Kandertal model was a wooded piedmont region with many hills and steep slopes.

To measure the whole DTM, it was necessary to divide it into smaller areas. The criterion to determine each area was the relief and that is why three kinds of areas were determined: flat areas, hilly areas and highly sloping areas.

Having in mind the same criterion, the strategy for the automatic creation of the DTM was chosen independently for each measuring area. The DPW Helava software has three basic strategies for the DTM automatic measurement: flat.strat - flat regions, rolling.strat - hilly regions and steep.strat - mountain regions. It appeared during the test, that it was necessary to measure the same model many times by using one or several independent strategies.



Kandertal model - photograph showing the 11 different zones used for precision analysis of DPW Helava correlation

The main goal was to achieve the best results and that is why the first terrain approximation was made by using the strategy for mountain regions. On the basis of this terrain approximation, the hilly strategy was used in the next measurements. The criteria of making the next measurement cycle were quick presentation of the DTM automatic creation results on a spatial terminal and the manual measurement of characteristic points or profiles by the operator.

The manual checking phase allowed to determine very quickly the differences between the real model and the temporary digital model. Finally, the whole Kandertal model was created with a mean error of ± 20 cm for the DTM height determination and the results for each region with the chosen strategies are shown in the following table.

Kandertal - results of the precision analysis of the Helava correlation
(flight height 800 m, picture scale 1:5000)

Zone	Control points	Strategy	σ(H)
1	39	rolling.strat + steep.strat*	±25cm
2	49		±27cm
3	20		±18cm
4	75		±19cm
5	18		±13cm
6	75		±19cm
7	56		±28cm
8	18		±16cm
9	80		±26cm
10	71		±12cm
11	11		±13cm

* rolling.strat: this strategy is used for more rolling terrain and accepts slopes up to 30 degrees.

steep.strat: this strategy is more time-consuming and accepts slopes up to 50 degrees.

According to the analysis of the test results, it can be stated that a precision of 12-28 cm can be obtained with the software package for the automatic creation of a DTM. This accuracy depends on the quality of the digital photographs, on the terrain configuration and on the correlation strategy chosen for a particular type of terrain.

The next conclusion is that it is very important for an operator to key in approximate height values of the terrain for a first interpolation of the digital terrain automatic measurement while defining the areas for the correlation. It allows to considerably increase the correlation accuracy and to speed up the software work.

The automatic filtration system for single spatial objects such as trees or houses which is part of the correlation strategy does not have the ability to define the object capacity for the process of searching and filtering. This disadvantage was the reason for which some mistakes were made during the creation of the DTM. Bigger single spatial objects were considered by the correlation system as part of the natural terrain surface. It is worth mentioning that the system for automatic filtration for single objects works properly on the natural terrain coverage like trees or single groups of bushes.

Another conclusion is that it is possible to increase the accuracy of calculation for a digital terrain model. It can be achieved by including additional information about the terrain configuration such as structure lines, break lines, single height points and the like to an automatically generated model. This information can be added either before or after the correlation process. The second variant allows to include some additional spatial information to a few first spatial interpolations.

The software package for the automatic measurement of DTM has one limitation: it only works on a regular network of measurement points. All additional information about the vertical terrain configuration included by an operator during the manual measurements, or taken from other digital models or GIS data bases are transformed onto the regular Helava point network.

During the study, it was also noticed that there is no possibility of performing digital terrain automatic measurements at measurement points precisely pointed by an operator. When working with the photograph correlation software, the operator can define the area and the density of the measurements points for this area, but he cannot interfere in the location of the measurement points.

Depending on the chosen strategy, the process of the digital terrain automatic measurement itself is the iteration process and requires 6-10 interpolations for the complete model creation. While the software is working, an operator can check the current work progress, as well as the approximate statistic information about the photograph correlation process quality. Because of the fact that the software works in the overwriting mode of new iteration results, it is not possible to view through all iteration process but only the final general rapport.

4. Conclusions

Although the correlation system has a few disadvantages described above, one must emphasize that it is highly efficient and requires a minimum efforts of the operator. The fastness to generate a digital terrain model for a whole area depends on the number of control areas created by the operator, on the measurement strategies and on the density of the measurement points. During the checking test, the creation of the whole digital terrain model of La Broye took approximately 1 hour for the orientation and 30 to 40 minutes for the whole correlation process, these times being valid for an operator very well experimented in correlation.

It is worth to point out that because of the new abilities of the DPW Helava software it is possible to initiate the automatic measurement system of a DTM as an internal process without starting the whole Helava system. It allows a more effective use of the workstation system and a more intensive operator's work.

There is a possibility of simultaneous process of creating several terrain models based on independent digital stereoscopic pairs. The digital photographs correlation system included in the Helava workstation software is an independent module which is not used only during the digital terrain automatic creation, but also during a few other work phases of the workstation like the automatic measurement of the fiducial marks during the interior orientation of the digital photographs.

The operator has to measure only two fiducial marks or their proximity to determine approximately the camera coordinate system and then the system computes all the others automatically. During the relative and absolute orientations, the correlation module automatically computes tie points and this helps to increase the accuracy of each observation made by the operator.

To summarize the results of the test, it can be stated that the Helava system for the automatic measurement of DTMs is one of the most interesting and versatile systems of terrain model automatic data that can be obtained on the market. Thanks to its high efficiency and editing abilities, the system provides very precise data which are easy to use in the production process of GIS databases, orthophotomaps and digital terrain models.

Discussion after the Conference:

Automatic Derivation of a DTM with the Helava System, by D. Gasior

Quessette:
How much computer time was necessary to achieve this kind of accuracy? Because we can always achieve a good accuracy with a lot of manpower and running time; it would be interesting to relate your accuracy to the processing time?

Gasior:
It is somewhat difficult to give you a clear answer for it takes a long time until one gets acquainted with the system. After various tests, I can state that a run of a model takes approximately 2 hours: one hour for orientation and preparation of all the files and about one hour for correlation and delimitation of the working areas (5 minutes for each control area). This is the pure running time, however, editing and checking should then follow. For the La Broye test model, I used 11 working zones and for the mountainous area of Kandertal, 11 zones were also chosen. In these special zones, no editing appeared to be necessary due to the special choice of the working areas. In the La Broye model, we have 3'600 control points and only 600 in the Kandertal model.

Eidenbenz:
Can you say something about the image scale of the model?

Gasior:
Both test models have a picture scale of 1:5'000 and a flying height of 800 m above ground. The pictures were scanned with a 10 µm pixel size.

General Discussion on Automatic Derivation of a DTM

Dupéret:
It seems like with Match-T, you are required to perform an epipolar re-sampling before you work. We do not have to do that with Socet Set, am I wrong or not? I guess Match-T gives more files to manage. Do you remove the raw images as soon as epipolar re-sampling is done?

Torre:
When we work in the Match-T environment, we do not use the original files of photo scanning, we only work with the epipolars.

Agnard:
Re-sampling is a time consuming process, and therefore, problematic. If you have already made a relative orientation, you can initiate a line searching algorithm because your software should correct for the Y-parallaxes.

Ackermann:
Of course, there are many possibilities. But one has many advantages if one can start with the resampled epipolar images, a process which only takes a few minutes per pair of photograph. In particular, one dimensional matching can be applied rather than two dimensional matching which would take much more time. That was at least the initial argument at the outset of the MATCH-T development.

Dupéret:
I remember the number given by Mrs. Torre. She said that it takes 45 minutes for epipolar re-sampling of one image and about 1.5 to 2 hours for one model.

Agnard:
The question was, are you obliged to re-sample and the answer is no. Of course, you can choose to re-sample, however, as the relative and absolute orientation were made, you can apply one line re-searching in one direction and nothing more.

Roth:
I just want to give the answer because it is time consuming to do epipolar calculations. Since we are also using the same algorithms, I think it really depends on the hardware you are using. I believe that if you use a very fast machine, you will have a better chance of getting epipolar images in 10 minutes. Also, it depends on the computer platform and which computer you use. Moreover, you have to look at the computer platform very carefully, as for the pre-processing and for the post-processing time, because this is when you have to do the real editing. Editing is just as important as image correlation to get a real DTM and as Mr. Loodts said, everybody wants to have a correct DTM, right? The best way would be for the user to just press the button and you would have nice and smooth interpolated contour lines. But we do not have such a direct automatic way of getting results, however,

we can automate all the steps as far as possible in order to reduce editing time on the machine.

Madani:
We are arguing here of doing one thing in different ways. It is apparent that everybody has different procedures. When we talk about epipolar versus non-epipolar matching, first of all, regardless of the time we are talking about here, it depends on the image resolution which you are using. When creating epipolar imagery, we do it either in batch or non-batch mode. Also, the 2.5 hours time which were quoted are in my opinion, not the amount of time spent for generating a DTM with Match-T. If you run the matching with 30 µm resolution, you are creating a DTM with Match-T in about 45 minutes. So if you add these numbers together, then 2.5 hours are not correct. The other point is when you use feature extraction, you have to make the epipolar images. The epipolar images by which you want to create DTMs and do feature extraction depend on the used algorithm and procedures. Once again, adding feature extraction, feature break line, points before or after running the Match-T depend upon how the system is working and what procedures are used.

Colomer:
Let me make an additional comment about epipolar re-sampling. We have been discussing a lot on the activities in the ICC. What we have seen with the Intergraph ImageStation is that in re-sampling the image and using smooth roaming for display, you reduce a two dimensional problem to a one dimensional problem. So the smooth roaming in the ImageStation you are enjoying partially comes from the reduction of the degree of freedom to one dimension. With the graphic card from a Silicon Graphics Computer, you can probably do it, you can download the transformation, sample on line at 1/60 of a second, and see a very smooth display. Again, I agree that this is a hardware problem as Mrs. Roth said. Do not forget, the ImageStation was designed some 5 years ago.

Kölbl:
I would like to ask a completely different question, not about re-sampling, but the precision itself. Mrs. Torre made a wonderful presentation, but I do not know whether I understood it clearly when she concluded that precision is sufficient to make orthophotos? On the other hand, if I indeed understood it correctly that Mr. Dupéret derived contour lines from the automatically generated DTM, then what precision did you get? Why did Mrs. Torre claim that the DTM is sufficient for orthophotos only and that Mr. Dupéret can use it for contouring?

Dupéret:
My customer is the IGN. My contour lines have to meet the specification of the database which I expect to do. We perform a statistic control to have a global idea of the RMS in elevation and it is absolutely necessary that I am under a RMS of 1 meter. The example I showed you delivered a RMS of 0.7 or 0.8 meter which depended on the chosen strategy, which included editing.

After that, doing the visual control is hardly necessary for the operator who is in charge of the cartographical operations. The operator decides how to present the surface properly thus, the final control is a visual one.

Torre:
To give you an idea about Match-T accuracy that we are talking about, we have similar experiences as written in the article of Krzystek, published in 1991. We normally got 1/5'000 of the flying height.

Agnard:
It has been assumed here that correlation works even in forest areas. This could be true, but not quite based on my experience in Canada where we have about 80% or more pine trees. I must admit that I have some doubts. The crowns look so different from one photograph to another where it might be in the center on one and on the other one, you look from the side. Correlation never works in this kind of forest. Our kind of forest consists of very small trees, which give us too many problems. So it is not a question of removing well correlated points which are not on the right position, but it simply never works.

Dupéret:
Just a remark on image compression. It seems that we can work very satisfactory with a compression ratio of 1:5. It might be good for other users to know that they have this opportunity.

Ackermann:
I would like to come back to the accuracy question. There are several levels to be distinguished. The first concerns the matching accuracy as such per point. It is known that feature matching and area have different accuracy in terms of pixel size. We obtain with feature matching a pointing accuracy of 0.4 pixel. Multiplied by square root of two we get the x parallax accuracy. Multiplied by the base height ratio we have about the height accuracy of the matched point. If we started from 6 µm feature accuracy the resulting vertical point accuracy is close to 1/10.000 of the focal distance. That is the basic vertical accuracy of the model points, not yet the accuracy of the DTM.

A DTM is a selection of points or a regular grid. Even if the grid points are measure directly, as in the Helava system, it is the size of the grid or of the mesh which is decively for the DTM accuracy. The question is how well this grid represents the terrain, almost independent of the accuracy of the actual grid points. As long as the terrain is relatively smooth, and as long as the grid is dense, then the point accuracy is almost the same as the overal DTM accuracy. We have had DTM results of smooth terrain, which were close to 1/10.000 of the flying height, or even better. But for mountainous terrain the DTM accuracy is poorer because the grid units (finite elements) cannot sufficiently represent the local shape of the terrain, even if the grid points would have no errors.

The third level of consideration of DTMs concerns the problem of terrain obstruction like vegetation, houses etc. That is a completely different problem which is independent of the actual DTM accuracy. It is, however, with regard to application, a point of major concern, for which we have no general solution, as yet.

Dowman:
I would like to ask a rather more mundane question. We have had a lot of discussion about how well the matching works and the problems of the gaps and the editing. If we accept Prof. Ackermann's conclusion that the matching works, but it matches the wrong things, then that really brings us down to the major problem of dealing with the editing. Therefore, I would like to ask the IGN, the ICC and everybody else whether the automatic matching is still considerably more efficient and more worthwhile in the production environment than going back to manual methods. And that what needs to be done about the problem of editing, what is the approach, what are the advances which are needed to get rid of this problem of filling in the gaps?

Dupéret:
We all feel that it is absolutely necessary to have the editing done after computation; presently, we expect to spend 50% less time with an automated process (including edition) compared to the manual plotting. I think that is favorable enough to start the job.

Torre:
From my point of view, in order to make the editing much easier, it would be suitable to implement additional functionalities in the system to help facilitate it. Because I believe that there are many internal statistic controls within the system that can give us a better clue as to where the matching failed and which surface reconstruction must be improved. In addition, if the break line can be obtained by the matching process, surface reconstruction can be more accurate.

Everaerts:
Has anyone considered producing stereo orthophotos and deriving an additional DTM from the rectified photos in order to correct the original DTM?

Torre:
We only made some tests. We tried to generate orthophotos from the right and left images. Then later, we compared the orthophotos, but the differences of the two images gave too many problems. When comparing the right image with the left image, one remarks great differences as for the texture and it is very difficult to interpret this phenomenon.

Ackermann:
Concerning quality control for DTM we have made some tests years ago at the university (Dr. Hahn) based on digital orthophotos in the following way: from the automatically derived DTM orthophotos of the left and right

images were produced, from which again a DTM was automatically derived. If the orthophotos were geometrically correct, then the resulting DTM would be flat because there shoud be no X parallaxes, except for 3 dimensional protrusions (houses, trees). The idea was to automatically locate houses and trees by height segmentation. The tests were not continued. I recall that there were some problems. But the idea is still valid.

Dupéret:
Last year, we have also done an experiment with 2 orthophotos like what Prof. Ackermann said. We wanted to test the opportunity of having a visual control, to see if it is really flat or not. But in fact, the human operator is so accustomed to see a tree with a shadow on the same side and even if the parallax is not correct, he sees correctly the shape of the tree or of the house even if it should appear as a whole or flat. The human brain is always correcting even if it should be flat, the shape is always in your mind.

Kersten:
I want to mention that Mr. E. Baltsavias from ETH-Zurich did some tests recently with the orthophoto refinement on the Helava System. His tests showed the result is better than DTM derived from the normal strategies. I hope he will publish something about this test sooner or later.

Héno:
I would like to ask what people think about accessing DTM via shadow surface representation like what Mr. Dupéret showed us?

Colomer:
We use it a lot as for quality control. In fact, besides the direct observation of the DTM, shading is our basis for quality control.

Dupéret:
I would like to talk about Mr. Ackermann's idea regarding multi-sensor. I think it is very interesting and I hope that the manufacturers and universities will work with these combined tools. I think this would be a very interesting opportunity to explore in the near future.

Part 4

Orthophoto

Direction :

J. Romeu

Orthophoto, as an input of Publishing Graphic Art.

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1. Introduction

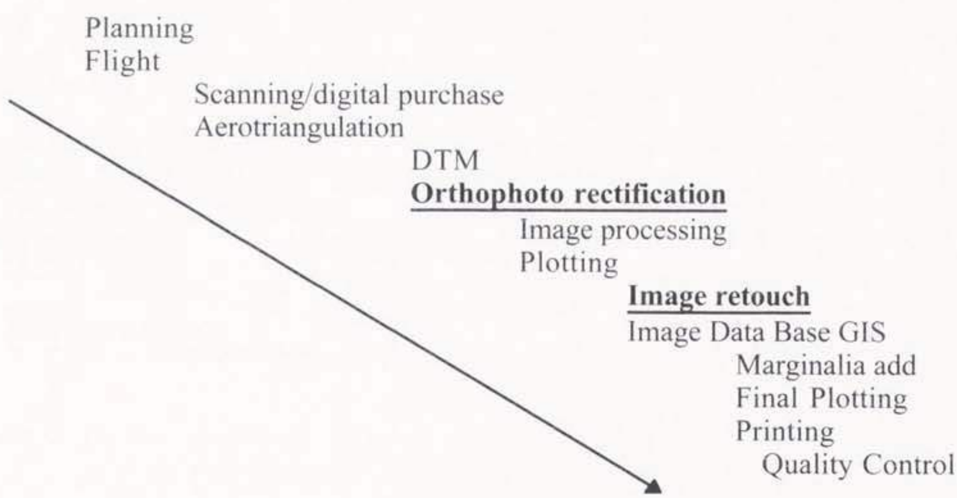
Year after year, commercial software offers more powerful tools in image rectification, and the use of this base information as an input in GIS domain increases the demand of digital orthophoto. Time after time countries with poor cartographic coverage need any kind of cartography to manage natural resources, land propriety, soils...

This convergence of facts seems to accomplish a happy end, but the reality don not match the facts with the consequences, and orthophoto generation is remaining in a complex and heavy environment of production. It seems reasonable to say that digital orthophoto rectification is nothing and orthophotomaps are a complex cartographic production line.

In this paper we want to discuss some considerations of this productive line focused in the fact that final aspects of the images are more interesting for customers, this aspects are traditionally linked to graphic arts tecniques. And we refuse to analyze how we do all the line because each line has its own configurations, especially adapted to each enterprise.

2. Orthophotomaps

To make orthophotomaps is a complex productive line, some parts of this workflow are in constant update (reducing times, increasing productivity, decreasing prices and creating new quality standards. From planning, full integration, DTM from Match-T to digital printing is a wide spectrum of activities connected to this flows that helps to the ORTHOPHOTOMAPS productions.



From our point of view the digital process of **Orthoimage rectification** needs only the 4% of the complete cost, and the less significant (in a photogrammetric point of view) **Image retouch** needs the 15 % of the cost in the whole production.

We talk indistinctly of **Orthophoto** and **Orthoimage** avoiding the semantically problem of each orthophoto is and orthoimage during the 90% of its process they lost the Photo suffix converted in a digital image. The fusion of satellite image and classical orthophoto increases the image processing due to the large experience in this field offered by remote sensing developments. This orthoimage work units empathizes the definition, color contrast and the final passes form digital to analogical products. Next discussions should be applied to the analogical photo captures an to the direct digital captures of images (appart from scanning films problems).

If we think in the problems of how to produce an orthoimage we find some considerations from the ICC point of view:

- We have no problems in aerial capture of images, even we are changing the parameters of output negatives (they has to be scanned), especially in B/W.
- Scanning became a solid technology (less of 8 % downtime),10 stations and 20 operators depend on only one device, and very precise (up to 2 Microns RMS)
- Aerotriangulation is going into digital.
- DTM by "classical compilation" and Match-T are fluent enough for ortho generation.
- Rectification is just CPU time consuming (few minutes), even in a modest PC .
- Mosaic technics are automated, even the discontinuity line tracer.

3. Intersection of orthoimages and graphics arts

Main problems of producing printed images (even digital printing) are in the final aspects of the completed sheet. This final orthoimage included elements as marginalia and toponymy and situation maps or administrative divisions that need more attention than the "heart" of the document.

Some words as calibrations are current used by working groups involved in the main objective of transfer digital information in a printed paper, and if it is possible, but in large series there is large number of maps that never are what the producer aims.

Color transfer from data capture to the final output is clear defined as a problem of communication. Cleaning scanned dirty and errors is defined as a source of problem but there is a solution using the same tools available for the printing professionals.

This positive merge of images representation are centered in a few important field of application concerned in a good representation of each individual or a group of orthoimages in a large series of image maps. This considerations are also valid for digital printing cases, just by changing some parameters, and adding some news (banding, register, life time of you plot ...).

- Tone reproduction of color and gray scale and large variety of contrast in a image.
- CMYK representation of an RGB computer world.
- Continuity in color balance in a series (especially in color).
- No external elements introduced by scanning an aerial photography.

Some of this problems are solved by appliying different methods, such as:

- Addition of large variety of color gamma during the film writing and reproducing them until final step of print.
- Retouch of scanned external elements by using commercial image raster edition software packages
- Elimination of reflections in water bodies (lakes, rivers) using mosaiking thechniques.
- Elimination of artifacts introduced in the scanning process (stripes, patch), by using commercial image raster edition software packages
- Sea continuity in a series using a constant background merged with the photographic capture of real sea.

Using this thecniques we found some solutions to our specific orthoimage work: solve the military censure and also some atmospheric artifacts, as clouds and fogy.

The main consequence of this constant search of the best picture for each individual orthoimage increases the human operation, and we are using the saved time by application of automatisation thechniques in different steps of ortoimage processes as:

- DTM compilation by correlation.
- Digital aerotriangulation.
- Mosaic automatisation.

We can decrease the operator time used in scanning, by introducing automated roll scanner, and this time could be used in more care of the final images.

4. Conclusions

Since the digital orthoimage generation was a sophisticated product and just few companies makes and prints, then the orthoimage was only a technical map. Now has changed because of the popularization of software rectification over cheap platforms and the continuous increasing of market.

Today, Orthoimages must be a precise map, and a nice picture too. We need the tools of the best nice pictures makers in different media to reach the standard quality of printing industries, but adapted to our particularities.

Discussion after the Conference:

Orthophoto as an Input of Publishing Graphic Art, by J. Romeu

Dam:
How much of your orthophotos are digital versus hard copy? And what are the differences in the problems of the presentation between the two types? What are the special preparation problems in digital versus hard copy orthophoto production? What are the tools that manufacturers maybe need to develop? perhaps there are special tools or work flows that would help produce digital orthophotos, because I think that is where the future is going, correct?

Romeu:
I think this is out of the question if you are asking for digital versus classical. Our work flow is purely digital and we have to do a lot of image manipulations. For example, we must change the formats to correct for dust particles. I could show you an edition of a raster image that might be astonishing. We have a project in Venezuela where we were requested to remove the dam from the image; they wanted us to transform the site somehow maybe because it is a nuisance for military operations. In principle, it is not very intelligent. Stupid things are more complicated because you never think about it. But concerning the requirements on editing, it is problematic to edit an orthophoto if you cannot see the completed orthophoto on the screen. We need to plot or enhance the details. At any rate, visualization of the orthophotos is problematic.

Eidenbenz:
One printing technique problem is the number of copies you want to stock in digital versus hard copy data. Another problem is the size of the map sheet for up to now the maximum is 84 cm due to the size of the printing machines. The problem then is that every customer wants his map specially designed by the map maker, so this gives us a real overhead to do every map ordered in a specific form and I am not quite sure if the user wants to pay this at the end. So you are sitting on your 6'000 orthophotos and you cannot sell them, but you have to print, at least let us say 500 of them to keep the machine running, so I think we have a problem there.

Romeu:
You are absolutely right. For each orthophoto, we make one copy per map sheet and then we produce it and sell it. The next one is produced in the same map shop, we already cut it, that means without direct control by the final customer. Our main occupation is to print copies and enlarge aerial photography; and we want to meet the desires of our customer.

Holmes:
Can I just ask Mr. Eidenbenz to enlighten me towards what you think a mapping office should do to stay flexible?

Eidenbenz:
Well I know that out of your database at the Ordnance Survey, you are printing on demand. The customer comes in and specifies that he wants this map centered on this house, in this environment, in this scale or so on; are you planning to do this also with orthophotos?

Holmes:
We do have an orthophoto production going on at Ordnance Survey at the moment. However, they are not designed specifically for that situation. They are produced more for actual map up dating. We see by-products possibly in that area, possibly specific things that customers ask for, but initially, we have not geared up to actually sell orthophotos as part of that super plan mapping which Mr. Eidenbenz quoted.

Becker:
I would like to make some comments on two points. The first comment concerns the actual printed output. I have been told that in the U.S., 70%-80% of all orthophoto projects are pure digital and no hard copies are required which is very interesting and implies a big cost factor. Orthophoto printing is one of the most expensive part in the production. If the client uses more and more digital copies, the demand is up, therefore, the price will go down. There are many packages which allow users to print on demand whatever he requires. Most old fashioned maps try to pack as much information as possible onto the map because it is required by a lot of different users. With the new GIS viewing technology, let's say many, if not all the users can produce the maps they require. In addition, they do not need to have a hard copy output because the hard copy is only needed in the field. Most analysis is not done in the field, but done in the office. So I think there is definitely a future more in the digital soft orthophoto than the hard orthophoto and the output is only required by a particular user.

That was one point, the second point was already noted. To make an orthophoto, it only accounts to 4% of the actual time, you press the button, you wait 5 minutes and your orthophoto is there. The rest of the 96% of the time is spent producing the product for the client and that is where the expense comes in. I think many clients are reluctant into accepting low quality products because of short cuts, so in that 96% working time, you can obviously eliminate a lot of steps. There are few standards in existence to define the quality of an orthophoto and I think there is something missing within the industry standard. Within the industry, however, someone should, maybe an organization like OEEPE should come up with quality standards for orthophotos – whether it is geometric or radiometric, what information is supposed to be available in the orthophoto, the quality of the mosaic, the type of output; these are real quality factors and there are no real standards to adhere to. And the requirements depend very much on what the client's use of the orthophoto is, but there are few standards to define that. Standard is something that is missing in the industry and it should be addressed by somebody.

Colomer:
Let me make a comment. It is probably true for the U.S., but in Spain, the number of personal computers per family or per person is still low. Currently, our major income comes from printing maps. This is probably unfortunate because you run into a problem of storing 1 million map sheets. We print vector maps on demand, but there is a limitation on the quality that we can offer to our client. Our 5'000 topographic maps are printed on demand on the electronic HP650C printer. But then you have to adapt your legend and your style to the output resolution. This is a trade off, however, we are pretty satisfied. We are trying to do the same thing with the orthophotos. One of our major users wants our orthophoto to navigate, but map names are surprisingly important on maps, even on GIS. Again in Spain, almost nobody travels with a family GPS. So if there is an emergency, they cannot tell the coordinates over the phone, so they obviously rely on geographical names. The geographical names for emergency studies are key factors for location. Putting, collecting and de-bugging map names make up the 96% of the work. If you are not strict in your cartographic standards, you can try to put it automatically, provided your software can do it. So at least in Spain, this is how we do it and this is the market we serve. We print nice looking maps with names!

Schroth:
I cannot agree with Mr. Becker. Maybe in the States it is different, but from our experience, it is similar to what Mr. Colomer was saying. In your company, we have the same experience. Of course, the people want to have the digital data, but they want to have the analog product additionally. The people are human beings who want to visualize everything and sometimes you can do this on the monitor. But most of the people who are involved in planning want the analog product to work on this still. Maybe we have to educate our clients to come to this standard that you were asking for, but the reality is completely different now and I think this will stay for some years to come.

Becker:
What I am saying is you are creating large costs in orthophoto production, which is not actually necessary for a lot of applications and this should be kept in mind.

Quessette:

Of course, we have to adapt the orthophoto maps according to the user's need because not two users will have the same requirement. For the final output, it could be digital or it could be a printed map, but it has to be adapted. One way to find a solution is to provide a map with an orthophoto behind with as few features as possible, in order not to hide the image that is full of information. Most of the vector data can be on disquette in a digital form and can be displayed on the PC. This solution is more geared to many professional users than personal users because not every family has a PC and a GIS. To combine the orthophoto map, you should print it on a piece of paper to have a full orthophoto map, otherwise, you will only have 800 x 600 pixel images which is limited. Additionally, it would now be the full set of vector data on the PC. With regards to the hardware solution, we can connect the map to the PC directly, you pin-point the paper map if it has been encoded with a special tablet, and you have on the screen the corresponding data sets to the point.

An Introduction to Digital Printing Techniques

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Summary

This article presents the most currently used technologies of printers today and the methods to reproduce the various gray tones or colors of a digital image. The limitations of these techniques are described herein.

Introduction

Today, desktop printers can reproduce images with a certain quality. This quality depends on the technology the printer uses and on the methods employed to simulate the various tones of gray (or colors). The following paragraphs deal with the most common technologies of today. In addition, different methods of dithering are presented and their limitations are analyzed.

Printer Technologies

Today's marketplace offers quite a variety of printing technologies, all with strengths and weaknesses:

1. Liquid Ink-jet

The basic principle of ink-jet technology is to throw out small droplets of ink through small tubes, called nozzles. They lay in a row on a printhead, moving across the paper. For color printers, the four basic components CMYK (Cyan, Magenta, Yellow, Black) lay side by side on the printing head, so the printing of color document is performed in one single process.

Several techniques are used to squirt ink onto the paper sheet:

a) Continuous ink-jet:

a pressured ink flow is thrown through the nozzles and separated into droplets by the high frequency vibrations of a piezzo-electric crystal.

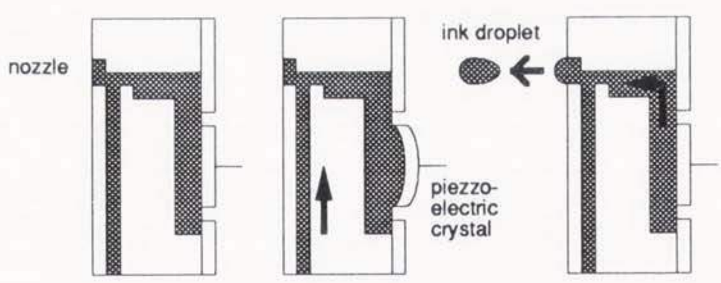


Fig. 1 *Continuous ink-jet technology*

b) Drop on demand:

a low pressure is maintained in the ink circuitry, retaining ink in the nozzle. A high pressure is produced each time a droplet is to be thrown away.

c) Bubble Jet:

ink is vaporized by an electric resistor within the nozzle, creating a small gas bubble. Under the pressure effect, a small quantity of ink is ejected out.

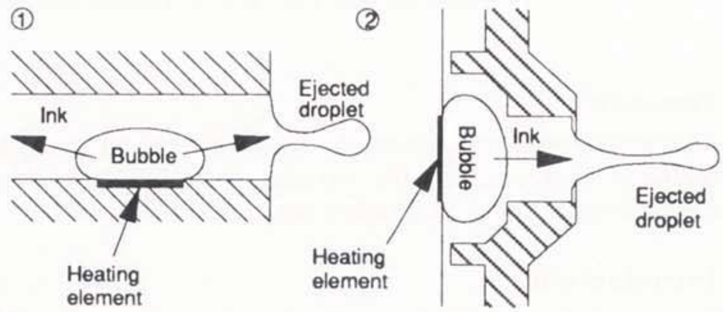


Fig. 2 *Bubble jet technology*

Future developments of liquid ink-jet technology will be the ability to throw two droplets on the same pixel. This will allow to produce pixels with two different levels of intensity, resulting in best quality outputs.

Advantages of ink-jet	Disadvantages of ink-jet
• cheapest technology	• needs special paper for optimum quality
• produces nice saturated colors	
• use of big paper sizes	• slow in low-end models

2. Solid Ink-jet

Solid ink-jet is based on the same principle that liquid ink-jet, except that ink is stored in solid wax sticks, which are melted in a small reservoir. The liquid ink is then squirted to paper, where the colored material resolidifies again.

Advantages of solid ink-jet	Disadvantage of solid ink-jet
• great for producing graphics on standard paper	• quite slow

3. Laser

Laser technology is the same as for photocopiers, that is to say:

1. A laser beam is sweeping across a photosensitive cylinder, creating on its surface an electrostatic latent image. The cylinder has the capability of producing electricity under light exposure.

2. The electrostatic image is then passed in a special powder (toner), whose particles are attracted by electric charges on the cylinder.

3. The image is transfer-red onto paper by electric voltage difference between the paper and the cylinder (2,000 V on the paper and 1,000 V on the cylinder).

4. The image is finally fixed by heating and pressure processes.

5. The cylinder is cleaned up, in order to get the next image.

Color documents are produced by repeating the process for each basic color.

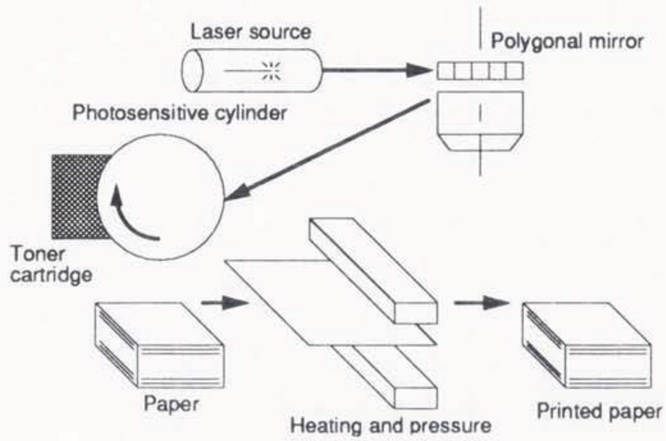


Fig. 3 *Laser technology*

Advantages of laser	Disadvantages of laser
• fast speed	
• long lasting result	

4. Thermal Wax Transfer

These machines use special colored films (a transfer roll), made of consecutive wax based material, that melts locally under the effect of controlled heating resistors. Colored wax is transferred by contact onto paper.

For color printings, the process is repeated three times, once for each basic color. Special paper is to be used.

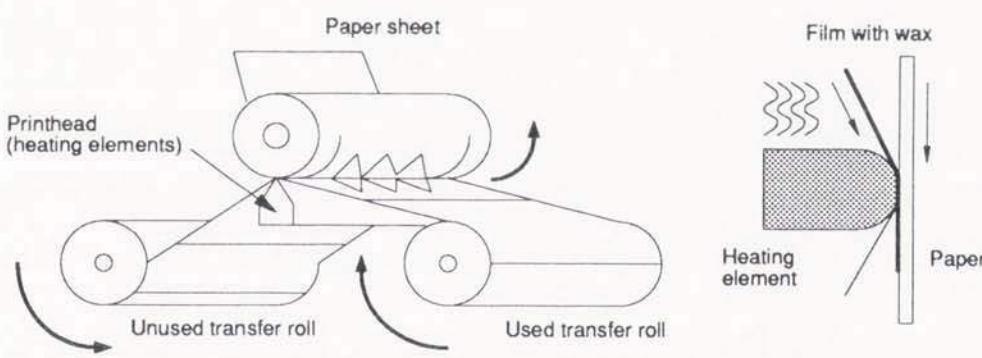


Fig. 4 *Thermal wax transfer technology*

Advantages of wax transfer	Disadvantages of wax transfer
• fast	• needs special expensive paper
• excellent color quality	
• precise elementary dots	

5. Dye Sublimation

This is the best quality technology used for printing images. The coloring agents are contained in a transfer roll (i. e. a plastic film that contains consecutive layers of cyan, magenta, yellow and black dye). The transfer roll passes across a thermal printhead consisting of thousands of heating elements, and once the dyes are hot enough to vaporize, they diffuse to the target paper's surface. The paper is specially designed to absorb the vaporous dye.

Each heating element produces 256 different temperatures, and the hotter the temperature, the more dye is transferred onto the paper. So, it is possible to control the intensity of the resulting dot and produce continuous tones images; dye sublimation is the only technology to allow it.

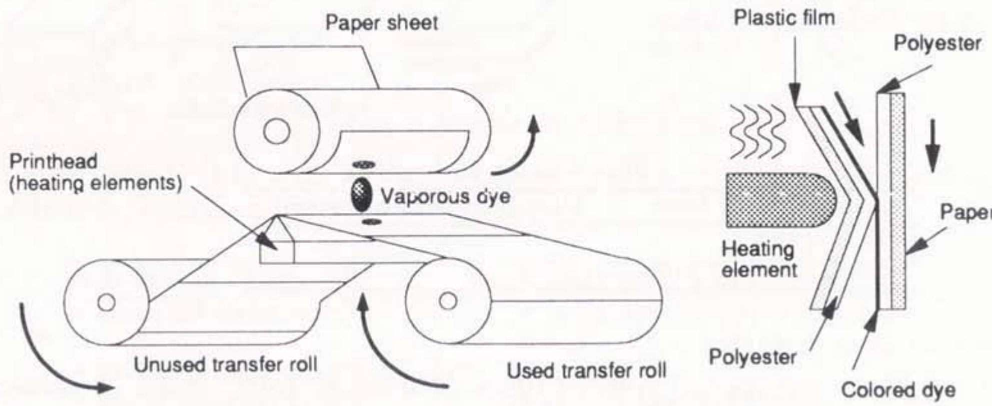


Fig. 5 *Dye sublimation technology*

Advantages of dye sublimation	Disadvantages of dye sublimation
• photographic quality	• high price of the transfer roll and the special paper

Dither techniques for digital halftoning

The problem

Except the thermal dye sublimation technique, each method is binary, meaning that paper either receives an amount of ink or not. Consequently, if one desires to reproduce gray scale or color images, halftoning techniques are to be used.

Since 150 years, halftoning has been used in the publishing industry. Most of today's digital printing machines use similar techniques that try to reproduce the different tones of gray with screen dots of different sizes, by grouping the elementary pixels of the printer.

Basic considerations

As presented above, most printers have a fixed output resolution; the size of the produced pixels are not sizable. Consequently, certain methods must be applied to decide whether each output pixel should be black or white.

There are four types of halftoning techniques, as shown in fig. 6. Two criterias define the type of halftoning. The first criteria makes the difference between ordered and irregular methods, where regularity means the presence of repetitive patterns in the reproduced image. The second criterion opposes patterns with spread dots to patterns where the dots are grouped to form clusters.

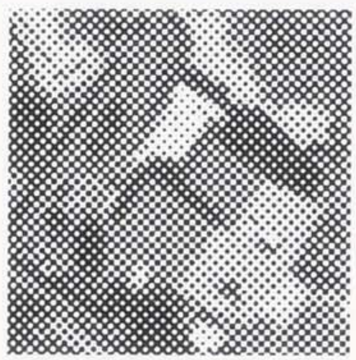
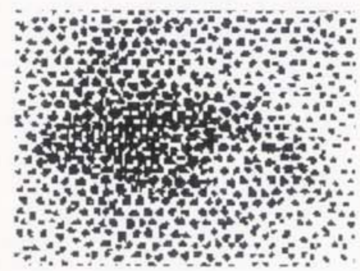
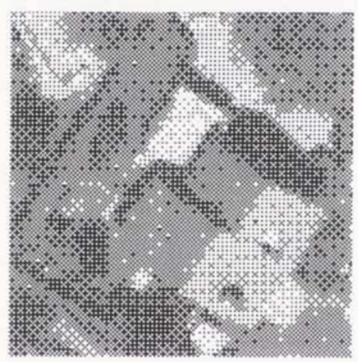
	Ordered	Irregular
Clustered		
Dispersed		

Fig. 6 *The halftoning techniques (magnified images). Upper right image from [5].*

Description of the techniques

Ordered clustered dithering

This is the mostly used technique in the publishing and graphic arts industries (found in the PostScript language). Digital halftones are produced by breaking the output image down into halftone cells, with each cell containing a single halftone dot. The halftone cell is made up of elementary pixels (the printer pixels), which are either turned on (making them black) or turned off (leaving them white) by the printer (laser beam or ink-jet printhead).

With such cells, the number of tones that can be reproduced is limited by the size of the cell. For an n by n cell, the number of reproducible tones is given by

$$n_g = n \times n \tag{1}$$

For example a 2x2 cell can reproduce 5 gray tones .

Then it must be decided if the pixels of each cell should be black or white. For that purpose, a threshold matrix is used, whose elements correspond to each pixel of the cell. So, the output plane is covered with regular patterns of threshold values, that is to say, that each pixel of the printer is attributed such a value.

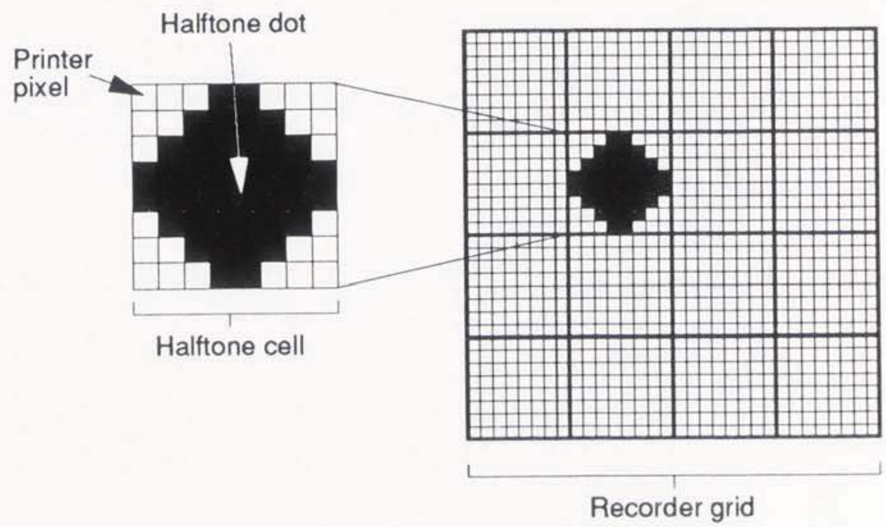
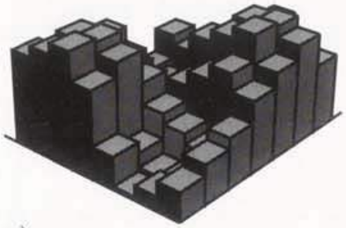


Fig. 7 *A halftone cell in its recorder grid.*

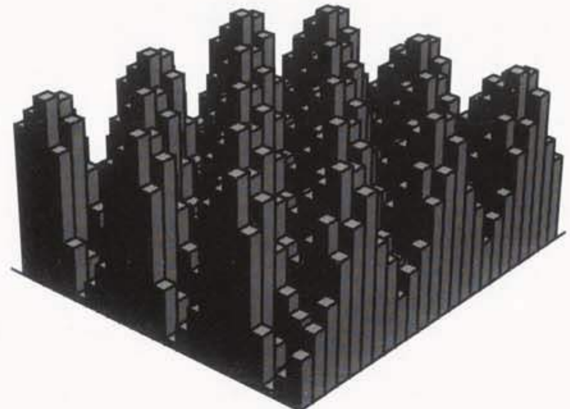
The reproduction process is to scan all the pixels of the output plane, and to compare the threshold value to the gray value of the input image. The condition used is given by:

$$G(x,y) = \begin{cases} 0 & ,if \quad g(x,y) \leq s(x,y) \\ 1 & ,if \quad g(x,y) > s(x,y) \end{cases} \tag{2}$$

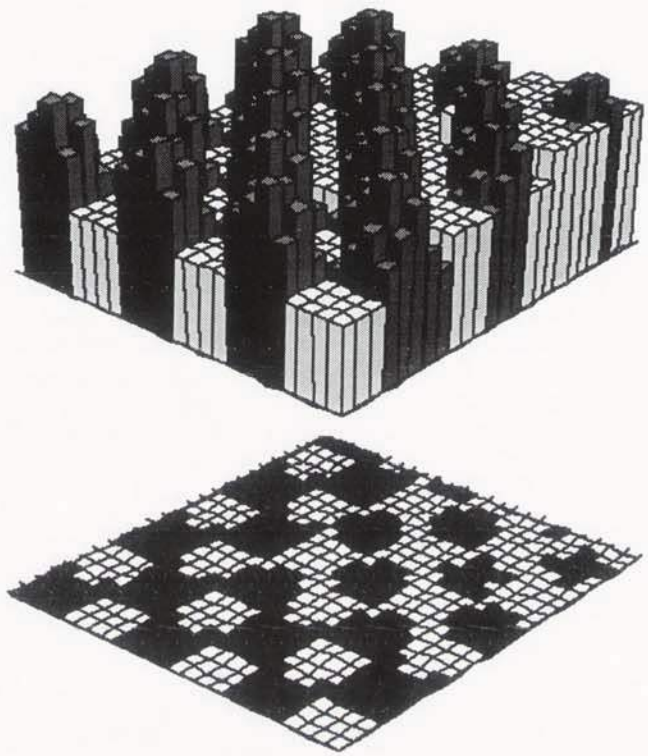
where G(x,y) is the output value, g(x,y) the input gray level and s(x,y) the threshold value. The process is depicted in figure 8.



a)



b)



c)

Fig. 8 *a) The threshold matrix b) The output plane (i. e. the paper sheet) is covered with such matrixes c) The halftone dots are obtained by comparing the image pixels (the light gray parts) levels to the thresholding values; if the threshold value is above the image pixel level, then the output pixel will be black.*

The choice of the threshold values is determined by an continuous function, called *the spot function*. Generally, it is chosen smooth and with positive and negative part symmetric, in the same way as an egg box (fig. 9). Then a period is discreticized to obtain the matrix shown in fig. 8 a).

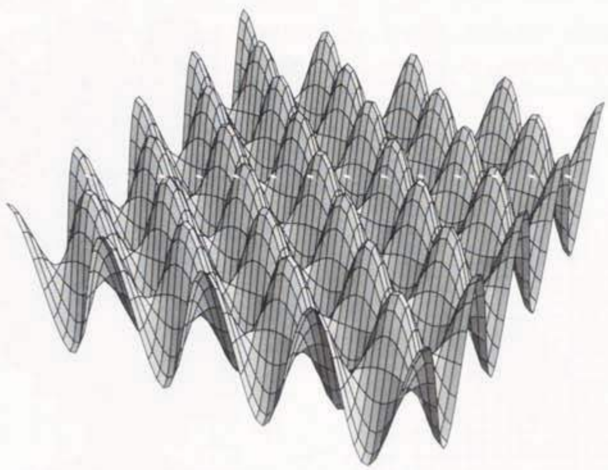
Ordered dispersed dithering

The only characteristic that varies from the clustered dithering is the threshold matrix. In the previous method, the matrix elements with close values were grouped in the matrix. In the dispersed method, the threshold values are uniformly distributed in the matrix. The generation of the output image is the same as formerly seen. The commonly used threshold matrix is defined by Bayer. It is as follows:

$$D_n = \begin{pmatrix} 4D_m & 4D_m + 2U_m \\ 4D_m + 3U_m & 4D_m + U_m \end{pmatrix} \quad (4)$$

where $m = n/2$, $U_m = \begin{pmatrix} 1 & \dots & 1 \\ . & . & . \\ 1 & \dots & 1 \end{pmatrix}$, $D_1 = 0$.

The principal advantage of this type of dithering is to smooth the banding effect obtained with ordered clustered dithering. An example is shown in fig. 10.



$$s(x, y) = \frac{1}{2} - \frac{\sin(\pi x - \pi/2) + \sin(\pi y - \pi/2)}{4} \quad (3)$$

Fig. 9 *The classical spot function, used in PostScript Language*

(a)

(b)

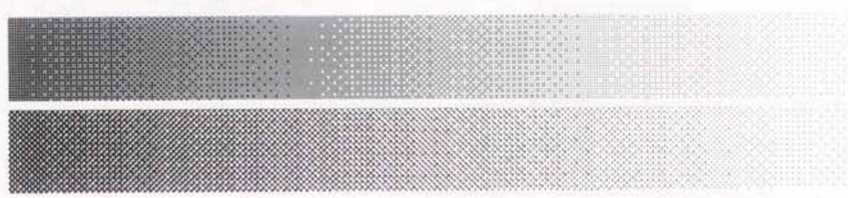


Fig. 10 *(a) Bayer dithering (b) classical halftone applied to a grayscale wedge*

Irregular dispersed dithering - error diffusion

The main idea in the present technique is to compute the best approximation for each output pixel, to determine the differential error and to spread it back on the neighboring pixels.

The original method was proposed by Floyd and Steinbeck. It consists in thresholding the gray value X at 50% and to distribute the error E on the pixels as shown in fig. 11.

	X	7/16 E
3/16 E	5/16 E	1/16 E

Fig. 11 *Distribution of the error in error diffusion dithering*

Fig. 12 *Patterns obtained with slow varying tones*

The main problems come from the path dependent result (i.e. the order in which the pixels are processed), and the appearance of disturbing patterns when handling slow changing tones.

Best results are obtained when noise is added to the image, before applying error diffusion process.

Irregular clustered dithering

The method try to divide the output image in pseudo-random tiles (i.e. cells). Each of these cells are thresholded on the base of the local intensity of the input image and the screen dots are clustered in pseudo-random patterns, the size of which are distributed around a chosen mean value.

Future methods

Recent developments [1] use pseudo-periodic super-cells (groups of cells), with rotation symmetries of order 2 or 3. This technique softens the appearance of banding in the reproduced image.Super-cells are a way of allowing to use small cells (consequently smaller screen dots, that are less visible) and nevertheless simulate more gray levels.

In addition, new technologies will allow to modulate the pixel intensity up to two levels with ink-jet technology, so that smaller screen dots can be used and the screening is less disturbing for the reader.

The extension to color reproduction

The former presented techniques apply to color images too. Practically, the techniques described above can be applied to the basic colors (i.e. cyan, magenta, yellow and black). The four produced dithered layers are then simply superimposed.

With PostScript halftones, the user must be careful with the orientations of the four layer, in order to prevent the appearance of disturbing Moiré patterns. The default orientations in PostScript are 45° for black, 15° for cyan, 75° for magenta and 0° for yellow.

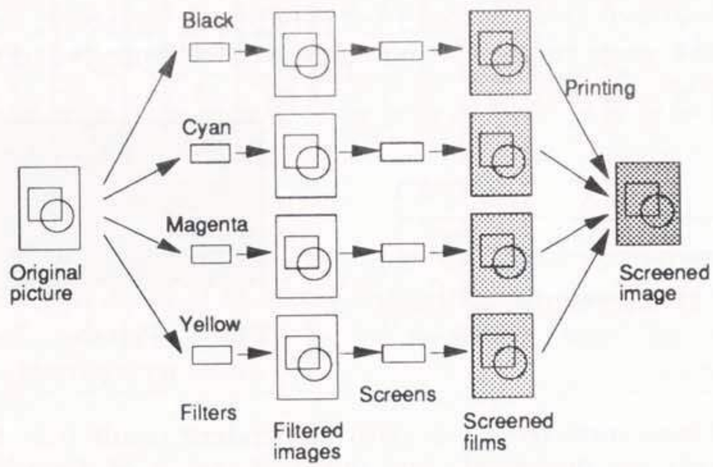


Fig. 13 *Halftone technique applied to color images*

The relation with photogrammetric applications

The implications towards orthophotos printing are of two types: geometric resolution and tone reproduction.

The question of resolution

As introduced above, the printers use a fixed recorder grid. Consequently, there is a relation between the number of printable gray tones and the spatial resolution that can be reached.

For example, if a user wants to print a 16 gray levels image, a 4x4 cell will be used, implying that a certain number of cells can lay on the surface of the output image. If the same image is printed with 64 gray levels, 8x8 cells are necessary, reducing the number of cells by 4 on the whole surface and the number of dot lines by two. In brief, the output image resolution is divided by two.

The other aspect is the resolution of the input image versus the resolution of the output product. Given that for a particular printer, the number of cells to be printed is fixed, there is no need to feed the machine with huge quantities of data (that slows the printing process), if they will not be used. The practical experience shows that more than two image pixels for one cell is useless.

For example, let us imagine that we want to print an image on an ink-jet plotter, the resolution of which is 300 dpi (dots per inch, i.e. the number of printer pixels in one inch). The paper width is 84 cm, that is to say 9'920 printer pixels. The default cell size for such a printer is 6x6 (i.e. 37 possible gray levels), corresponding to 1'650 cells for the whole width. In the optimum case (the best resolution is reached with one image pixel for each output cell), it represents 1/14 of a scanned aerial image (23x23 cm) with a pixel size of 10 μm.

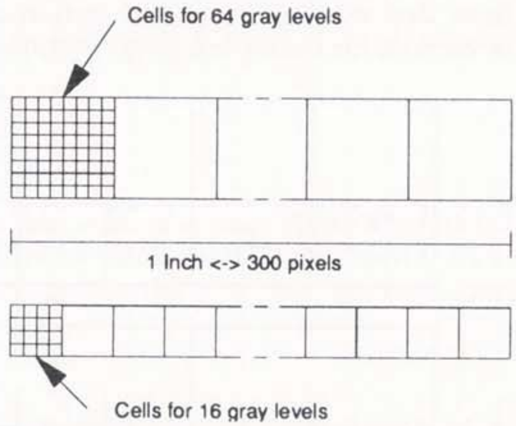


Fig. 14 *Resolution versus number of gray levels*

Table 15 presents the resolutions that are possible with a fixed number of gray tones. These values can be compared to publishing machines, with resolutions up to 5080 dpi.

nb. of grays	16	25	36	64	256
300 dpi	75	60	50	37	18
600 dpi	150	120	100	74	36
5080 dpi	1270	1000	850	630	315

Table 15 *Resolutions (in lpi, lines per inch) for fixed number of gray tones with 300 and 600 dpi printers andpublishing machines.*

The question of tone reproduction

For most scanned aerial images, the number of gray levels is 256 (8 bits coded image pixels). For the reasons described above, the number of gray levels is generally reduced down to 36 or 25. This introduces a loss of information between the original image and the version with less gray levels.

The other aspect concerns the density values obtained with a printer. For that test, we used a 16 gray levels gradation, which was printed on an HP Design Jet 650c plotter (ink-jet technology). We then measured the density of the 16 zones with a Macbeth TR524 densitometer. The results are summarized in table 16.

We notice that the dynamic range is nearly 1.3 D. Compared to an aerial photograph (common dynamic range of about 2.0 D), it is inferior of 0.7 D, that is a factor 5 when converted to reflectance.

So with such a limited dynamic range, the user is often obliged to adapt the gray tones, in order to lighten the pixels. This problem is increased by the fact that the droplet of ink spreads on the paper and creates a larger surface than desired. A correction function can be introduced to attenuate the phenomenon, for example a gamma curve.

	Zone							
	1	2	3	4	5	6	7	8
Gray Value	0	17	34	51	68	85	102	119
Mean Value [D]	1.282	1.238	1.162	1.080	0.982	0.864	0.746	0.630

	Zone							
	9	10	11	12	13	14	15	16
Gray Value	136	153	170	187	204	221	238	255
Mean Value [D]	0.550	0.482	0.402	0.332	0.248	0.158	0.090	0.000

Table 16 *The measured density of 16 gray levels printed with an HP Design Jet 650c plotter (zone 1 is black and zone 16 is white).*

In conclusion, before printing an image on a printer, the operator must check the following points for doing a good job:

- the printer resolution (in dpi)
- the size of the desired printed drawing
- the resolution of the screens (in number of dot lines per inch), remembering that this resolution is bound to the number of gray tones
- the size of the file (the number of pixels should not exceed the number of cells by a factor 2)

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Discussion after the Conference:
Digital Printing Techniques, by D. Meylan

Becker:
The resolution of the different printers, for example, the HP650C, I think they are up to 300 dpi in colour and 600 dpi in black and white. Do you have any idea how far this technology can go in the future? Is there any theoretical limit to this technology?

Meylan:
In terms of popularity, ink-jet is the most popular one in this field. As far as resolution is concerned, I think it will not go further beyond 600 dpi. However, an Epson printer already has 720 dpi. I think the improvement will be seen in the multiple level technology, which will produce far better quality images. I know that with the laser technology, they have now achieved a resolution of 1200 dpi. At the moment, it is very difficult to speculate where the limit would be.

If you want to create an orthophoto, it is normally printed on a large size paper, so the only printer that you can use is the ink-jet and not the laser, nor the dye sublimation. Although the dye sublimation technology gives an excellent result, you cannot print a very large paper on this machine. In any event, I think ink-jet will stay for awhile.

Part 5

Plotting

Direction :

C. Dekeyne M. Torre A. Dupéret

Applications of Digital Photogrammetric Workstations : Digital plotting

C. Dekeyne

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Summary

The paper at first reviews what are the tools needed for photogrammetric data acquisition in an application such as topographic database constitution and updating. It then describes the issues of stereoplotting on Digital Photogrammetric Workstation as far as this kind of application is concerned. These statements are based on actual experience at the Institut Geographique National - France.

1. Introduction

This paper aims at showing perspectives in stereoplotting using Digital Photogrammetric Workstations (DPW), compared to analog and analytical stereoplotting.
It will first emphasise on the needs for stereoplotting, then scope on DPW and digital images, and the consequences on digital plotting, either productivity or quality.
It will give information based on real experiences (ICC, IGN), in large scale or small case surveys, for new map (or database) making, or for existing maps and database updating.

This paper does not pretend to cover every existing DPW users problem in stereoplotting, and should be considered as a position paper upon which further discussion and assessments should be initiated.

2. Stereoplotting : What are the tools needed for data acquisition ?

2.1. State of the art

Every analytical plotter is offering data acquisition components. Some of the manufacturers claim that a real GIS module is connected to the plotter, while others only regard their acquisition software as CAD-CAM modules. It seems that the tremendous encrease of GIS demand encouraged manufacturers to claim the connection with GIS modules.
In fact, users are generally awaiting from their photogrammetric equipment good data acquisition and editing functionalities with good management of the third dimension which are only a little part of a Geographic Information System.

Let's review in the following paragraphs what are the functionalities required (we will use the word GIS to call the data acquisition and editing software used for stereoplotting).

2.2. Data model (Descriptive level, geometric level)

First of all, you have to define a data model for your application, to describe all the features that you have to manage. Main characteristics of the data model preparation are :

- It is possible to define features, with attributes, or simply codes for every entity.
- A feature may be defined as a point, a line, a specific type of line (spline, curve, circle..).
- Surfaces features may or may not be handled.
- Every point is 3D defined, but there are not any management of vertical objects (lines or faces). That's why it is often said that the GIS are 2 1/2 dimension software.

2.3. Graphic handiing

Graphic handling of data is a very important task. Users starting to use GIS with stereoplotters have to be aware that it is time consuming to define a satisfying symbology for an application. A comprehensive graphic management may include the following functionalities :

- It is possible to graphically represent points lines, break lines, contours with dashed lines or patterns.
- It is possible to set display priorities between features (very useful if you want to use full patterns for surfaces).
- It is possible to set different symbols according to display scale.
- It is possible to define several legends (association "feature-symbol")

2.4. Data acquisition tools

Input devices :

- Data acquisition tools are accessible through pedals, indicating new point to be captured, the end of an object or other functions. The altitude is set with a foot disk. All these input-output devices may be track-ball and mouses (P-mouse) devices on some of the manufacturers solutions. (ex : P-mouse on the image station, pedals+ handwheels on the Helava station).

connection functions :

- There are connections (sometimes called "snaps") possible to existing elements (existing point, or creation of a new point in the line segmentation).
- Z information on these connections functions may be managed in different ways : Privileging the new Z indicated by the operator, keeping existing Z (existing point or interpolation between points), or both aspects using tolerances.

Dynamic capture :
- Automatic data capture, using time and/or distance filters, plus bending filters, keeping at the end the amount of points strictly needed for keeping the aspect of the element (ex : contour lines can be captures in a dynamic mode).

Cartographic tools :
Used in order to give to the photogrammetric plotting some cartographic qualities. A non-exhaustive list may be :
- parallel lines (keeping Z information)
- rectangularize functions
- feature alignment (shape vs shape, shape vs line)

Editing tools :
These tools can be very sophisticated. They may also spoil some of the work made if there are not carefully used (ex : loss of z information when moving a point or a line).
- moving a point
- delete an object or a part of an object
-extending lines

2.5. Topologic tools

Topologic tools depend on the level of topology which is managed by the system. Let's try to define 4 different levels for topology management :
- Lines and points, no connecting or "snapping" functionnalities This is a pure "spaghetti" system. It will be really difficult to exploit such data for further processes including topology.
- Connecting functions, no surfaces management.
- Connecting functions, surfaces management. Most of the system with this level of topology manage surfaces with perimeters, those perimeters can be constructed using existing lines (shared primitives).
- Connecting functions, surfaces management, topology creation, interactive or batch (intersection detection, undershoot , overshoot management). At that level, most of the system may react differently facing the Z management problem. Will a topologic node accept to keep different Z information, depending on what line it belongs to ?

2.6. Data importing and exporting

Most of these GIS systems offer DXF transfer (import or export), or other home-made ASCII format. This function is essential for data transfer with other production workshops (cartography, editing).

2.7. Plotting

Plotting should be understood as draft plots that may be useful, at the photogrammetric stage of a production process, for control tasks.
Most of the GIS offer these plot capabilities, but they have various complexity.

2.8. Queries

Query language on descriptive and geometric level on data can be very useful for quality control. You may want to check for coherence between contour lines and spot heights, continuity of road or hydrographic network, etc.. Symbolization of query results can be useful as well.

3. Stereoplotting with DPW

3.1. Introduction

Digital Photogrammetric Workstations are now being used in production and even though stereoplotting is not the main application, all of them offer digital data acquisition capabilities, with the same kind of parameters that we described in the chapter 2.

We will now review what advantages or disadvantages DPW may provide in a photogrammetric data acquisition production process.

3.2. Use of digital Images

Ergonomy - environement

With DPW, the operators are much more sensitive to any motion coming from outside. There are no longer isolated right upon their photographs with black surroundings in oculars. They are very sensitive to outside light and reflections on to their working screen, so that they should work in semi-dark rooms.

Environment of DPW should be carefully analysed to limitate lack of productivity due to outside disturbancies.

Stereo viewing

What are the consequences of stereoscopy on DPW on productivity and quality of captured elements ? There 4 ways on DPW's to get 3D perception :

- Active glasses (crystal eyes) : they are efficient (no light loss). They are not as constraining for the operators as it was "redouté" (at ICC, no eye's strain of any kind after 7 hours of continous work). The flickering effect has to be stopped when the operator looks at a control screen.
- Passive glasses with polarizing film on the screen : they are comfortable (like sunglasses) but this technique involves a marked light loss.
- Split screen with stereoscopes : inexpensive but uncomfortable(the stereoscope has no settings, it is difficult to get the correct body position), and the part of the stereoimage seen in 3D is narrow.
- anaglyphs : inexpensive, but is a strain for the eyes and reduced interpretation.

Image quality

In most of the production companies, aerial photographs are carefully checked before they are validated for further processes (triangulation and data capture). Do we have to increase quality control operations for DPW or is it useless, since we have two new stages before stereoplotting : scanning and image processing ?

There are no answer so far, but we have to think that image processing can be a heavy workload if we aim at improving a poor image quality. Operators are generally not qualified for image processing tools handling, except for contrast or brightness enhancement and histogram balance.

Scanning

Scanning is a non-easy stage in the production process and problems encountered will not be described here. Anyway, production workshops should be ready to face scanning problems, especially if they get their images from outside. This control process has to be fast. Can he be exhaustive (i.e do we need to display every photo to check their geometry and radiometry) ?

Minimum tasks should be set up in order to avoid troubles :

- Check geometry : carry out inner orientation on a sample of photographs. This may detetect default in scanning
- Histogramm checking : this may detect a wrong spread of pixel values.
- Other controls (noise) should be assessed beforehand, when choosing scanner (your scanner, or the sub-contractor scanner). Companies may not afford other heavy controls.

Pixel size for plotting

This will really depend on the plotting specifications, but there are simple rules to check out :

- Do we need in our application any smaller pixel size than for plotting (orthophoto, correlation)
- What is the correct display scale that I want to get in order to facilitate the interpretation work ?
- How fast will I have to refresh screen ?
- What kind of stereo image display I get on my system ?

Experiences (particularly here at IGN) showed that operators are sensitive to image noise, but that they need to identify image details, especially in urban areas. We discovered that an operator is more sensitive to the image quality (camera, scanning) than to a difference of a few microns in pixel size. A manufacturer (Matra -Cap) offers the possibility of a local sub-pixel accuracy for precise stereo measurement (local resampling of the image up to 1/16 of a pixel), arguing that it allows to scan the images at lower resolution, which largely reduces file size.

Anyway, different zoom techniques can be an alternative to pixel size : The use of cubic convolution in zooming can be sufficent for a certain type of areas (ex : 15 microns in urban areas for updating process from 1 : 22 00 scale photographs - ICC Barcelona) but a smaller pixel sizer will be necessary for other delicate areas (extremely dense areas - ICC Barcelona).

Stereo Image display

This is a crucial point in stereoplotting : the operator is used to *moving-image-fixed-cursor* since it's the way he works on analog and analyting plotters (floating marks are fixed !) . He will need an acclimatization to the *fixed-image-moving cursor*, and will get some difficulties in the image corners (depending on image pre-processing).

Performance of image roaming is essential : this is mainly a problem of cost, and inexpensive systems generally do not offer this *moving-image-fixed-cursor* possibility. Other systems reduced drastically the image size on diplay screen, arguing that operator only looks at the immediate surroundings of his floating mark.
Strategy for image roaming or refresh could be discussed as well : continous roaming with cubic convolution display is a strain at certain display scale. Performance with vector superimposition can decrease when operator come to the end of data acquisition for their stereomodel.
Cursor jumps, especially on interlaced diplay mode are an other discomfort for operators.

Image processing for digital plotting
The main processes used are the zoom images computation and the epipolar transformation of the images.
Epipolar process is recommended. Some people say that it may damage image information, other that it facilitates stereoscopy and reduces eyes-strain.
Other processes (filters) should be carrefully put into operators hands : some of the image processing functions will be adapted to a specific interpretation (feature sharpeness effect), degrading some other part of the images.
Nevertheless, such processes (bilinear or cubic convolution filters) can be added to the epipolar process.

Data management
This is an important cause of loss of productivity if hardware is not adapted to the image file management (compression board, high speed network, etc..). This aspect will not be detailed here (cf. Topic 6).

3.3. Orientation procedures

Interactive orientation procedures may be much more difficult using DPW, since they require precise parallax settings, and correct identification of control points. For this task particularly, operators would appreciate smaller pixel size.
On the other hand, orientation procedures may be fully automatic on DPW's. Inner orientation can be done automatically and outer orientation is now assisted with correlation and in most of the cases it will be easy to carry out correlation.
It is advised, in a fully automatic orientation process, to work out quality check of the outer orientation with operators.

3.4. Digital data acquisition

Image super-imposition
This technique consists in displaying digitized elements both on to the right and left images, into photo-coordinates, On analytical plotters, this is done through CCD camera's, of which vector images are injected into each optical path through prisms. . This allow a real-time quality control for the operator (3D quality, exhaustivity control). This superimposition may be

B&W, or in color, and needs to be calibrated. There are nevertheless disturbances caused by this system :

- Vector thickness should be close to zero and intensity softly tuned, in order to leave the eyes concentraded on the photos and not to the 3D vectors).
- The display patterns should be turned off, not to hide the images !
- The colors should be carefully chosen

This functionality is presented as a great advantage of the DPW devices, because it does not require any additional and costly device. It brings up possibilities for colored-symbolised vectors superimposed to the images. It allows quick recognition of changes and fast error detection (in an updating process).

Superimposed vectors, even though they can be reduced in width, can have a stairs aspect especially for small details with Z differences.

To be fully efficient, we need to implement a specific symbolisation for the 3D screen, and this symbology should be variable according to display scale (for exemple : do not display houses at a scale smaller than ...).

GIS software

The main difference between DPW and analytical plotters, in terms of GIS, is technically how the superimposition will be managed (i.e can you access to all the editing functions directly on the 3D screen ?).

An other fact is that you are limited to the commercial offer : Some manufacturers follow their product from analytical to digital, some other take the opportunity to settle new alliances between photogrammetry and GIS worlds.

The problem for the user is that he cannot optimise both aspects, and can face difficulties in trying to diversify.

Semi-automatic tools

Correlation and image processing brings up new possibilities for feature extraction and these tools, in theory, should increase productivity.

So far no one uses such tools in production, since many aspects are still under research, especially for planimetric feature extraction (roads, buildings and so on). Extraction of DTM and contour lines derivation from it are much more advanced and should be used in production soon (i.e 1997 at IGN, for 1 : 25 000 scale maps production). cf. Topic 3

Anyway, the production staff should be aware that this kind of tools (DTM edition tools, contour lines derivation and smoothing) will not be used by photogrammetrist operators without heavy training programmes.

DTM use in plotting

DTM can be used in plotting to constrain the Z on to DTM, without adjusting any Z pedal. This fonction may be useful for non-photogrammetrist operators, especially in updating purposes.

3.5. Updating

DPW seems to be a quite appropriated tool to carry out photogrammetric updating of existings maps or databases. Performances of the station, which are quite sensitive for initial data collection seems less critical here, and

superimposition offers an overall aspect of the database upon new photographs.
Even with this very positive point, photogrammetric updating faces many difficulties :
- The new aerotriangulation : doest it have to fit the terrain or the existing data ? In the first case, the operators will have in many cases the trend to move existing elements to new photographs. This involves many manipulation that may damage the consistency of the data base. For example the operator should like to move the z coordinate of a few construction points of existing elements.
- An updating process will have to specify very clearly what are the tolerances which are accepted for existing elements.

3.6. Productivity assessment

A few years ago, the answer to the question "Why go digital ?" in photogrammetry would have been no, especially for stereoplotting processes.
The question could be reconsidered now, with some real experiences carried out in a few companies. Productivity can be preserved if these rules are followed :
- reliable scanning
- simple image processing
- automatization of orientation procedures
- high performances in image roaming
- ergonomy of DPW (light, environment)
- GIS with efficient superimposition possibilities
- easy to use GIS, preferably with low topological level, but good management of snapping (with correct Z management).

3.7. The operator's point of view

Photogrammetric operators in most of the cases are enthusiastic about new technologies. They worry about working conditions and comfort, performances in image display, but dont see any loss of productivity if these conditions are fulfilled.
On the other hand, they feel concerned about the prospects of their job, what new qualification they will need, and regret the automatization of orientation procedures, for example.
Experiences we had recently on DTM editing for semi-automatic contour lines production have been quite successful so far.

3.8. Conclusion

Before semi-automatic tools can be operational for feature extraction, companies using stereoplotting with analytical plotters wish to preserve tools (captue) and image quality (display, stereo) they are used to when they are thinking of going to digital plotting.
Nevertheless, the higher advantage of digital stereoplotting seems to be the vectors superimposition on stereo-image screen, especially in updating conditions.

Discussion after the Conference:

Applications of Digital Photogrammetric Workstations: Digital Plotting, by C. Dekeyne

Agnard:
When you said that split screen is uncomfortable for stereo vision, can you elaborate more on that? It is difficult to imagine a better body position than on analog plotters or do you mean that operators for half a century were uncomfortable? Because I do not see any difference between the two means as far as the attitude of the operator is concerned.

Dekeyne:
We were very concerned about how the operators felt with the new stereo viewing facilities. We have tried the split screen, but I did not say we had much experience about it. We have the polarization glasses experience and I can say that we are comfortable. We have very little experience with the split screen and stereoscopes. I think operators say that they suffer from a slight strength on viewing–that is what we experienced. However, Mrs. Torre can give some indications about the crystal eye glass equipment in the production process, but maybe you have some information about the DVP equipment in the production process and how the operators feel.

Coulombe:
We developed the DVP, but we also have a service company. We have an operator who works 8 hours a day and never complains. I think it is only a matter of getting used to something. They never tried anything else, but doing just that, they simply got used to it.

Eidenbenz:
Did I understand you right that IGN-Paris is only equipped with one digital production unit? And how many production units do you have running in total now?

Dekeyne:
We are still increasing our production potential to let us say 24 analytical and 12 digital work stations in the next two years. The question in the next few years will be on how to do the updating. We will have to update the database if customers demand it, and the question will be whether to replace the analytical equipment?

O'Sullivan:
I would like to know how you deal with updating your raster data?

Dekeyne:
We do not produce nor update raster data, we just produce vector data. Of course, we use a photo coverage in form of raster data, but we do not touch it. In the research aspect, we do not hear much about research in image

processing for the updating purposes of a database in vector form by comparisons of different images, but this is just another question.

Of course, in the process, we have field completion; first, we do stereoplotting and then the operators go for field completion. Until now, the data collected were in 2D, and when we first updated the data of course, we had to deal with the 3D super imposition. What we have done so far is, we got the DTM derived from the existing contour lines to get the height information to the point. But of course, the plotting is a lengthy process. So far, we only worked with the analytical plotter in the production environment. That is why I said we hope to do much more with the DPW for updating, because we will have a more refined DTM and we will get a much higher precision, I hope so. That seems to be confirmed by our first experience.

Coulombe:
Some people complain about the split screen and that it is time consuming to refresh the screen. I would say that in the production environment, the operator cannot work a full 8 hour day without having to relax. The operator definitely needs to stay away from the screen for a little bit. I would say that this is not a waste of time in production.

Kaczynski:
The split screen presents another danger for the operators because of radiation. When you are working with the split screen and stereoscopes, you are very close to the screen. As an operator, if you work 8 hours a day for 5 years, you will be in the hospital soon, I suppose.

Experiences with the Imagestation for Data Capture

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1. Introduction.

At the Institut Cartogràfic de Catalunya the Imagestation has been integrated in the Data Capture production environment since the end of 1993.

At this time the environment is composed by eight Imagestations. Seven of them are devoted to data capture as well as DTMs generation and revision. The one that remains works in digital aerotriangulation and as a server, delivering epipolar images to the others.

2. Digital Images.

After doing some tests we decided to go into production with the following input data

Input images	Resolution (microns)	File format	File disk space (Mb)
B W	15	JPEG compressed	65
color	30	JPEG compressed RGB	33

3. General Display.

Zoom factor
It depends on the area where the operator is working. A simple classification is:

	Flight height	Screen scale	Zoom factor	Output map scale
Urban areas	2500	1:350	2	1:5,000
Urban areas	1000	1:225	2	1:2,000
Open areas	2500	1:700	1	1:5,000
Open areas	1000	1:450	1	1:2,000

In very crowded urban areas the zoom factor increases up to 3. And the zoom factor used in extremely dense forest areas, where the perception of relief is difficult, decreases to 1.

Bilinear interpolation is used when the zoom factor is larger than 2.5 this causes a reduction in the roaming performance.

Data Display
During data capture is very important to count on smooth roaming - fixed cursor and moving image-.

It is very important to select an appropriate color palette, for better and fast image data interpretation, specially when working with color imagery.

During stereocompilation is suitable to avoid the display of pattern symbology, otherwise the dynamic movement will slow down. It is better to classify the elements by the simplest symbology ie: color.

All the 2d information contained in the design file will disturb the stereo perception, mostly in very crowded areas.

Screen setup
Since the release delivered by Intergraph in August 95 allows to deal with more than one dynamic view, the screen has been customized in this way:

	Displayed area	Movement	Contents
3d master window	Around the cursor at selected zoom	Continuous roam.	The graphic info.levels related to the element that is being compiled.
2d Top detail window	Small (1/5 master window) around the cursor.	Tacking.Roaming in discrete step.	The info needed to check cartographic constrains (alignments, orthogonality...)
Overview	The whole working area	Fixed. Only moved by window commands.	All the compiled information

4. Data Capture

We have developed the software of data capture on top of mstation using Mstation Development Language (MDL).

MDL makes easy to develop some data capture tools as:

- Strict copy parallel of a 3d polyline. It means that the elevation of each point in input line will be kept in the parallel one.
- Automatic snap when crossing features ie: automatic snap to a breakline when compiling profiles.
- Orthogonalization functions.
- Visit points of a linear feature.
- Relative movements between windows. Move the master window to a given point defined in the overview.

5. Image enhancement tools

We can distinguish to steps where image enhancement tools are applied:

- During data capture time: These tools must be fast and adaptable to feature interpretation. During stereoplotting, only gamma adjustment and linear functions are applied to the histogram. Gamma correction is used frequently by the operators.
- In epipolar sampling: Cubic convolution is applied during epipolar sampling to get a sharper image.

6. Final remarks

The operators that work at the Imagestation come from analytical stereoplotters.
From our experiences the training period is:

- Two or three days of intensive training to get in with the new environment.
- In average it takes three weeks to achieve the standard production ratio.

The downtime represents up to now a 2.3 % of our working time. The 0.5 % is due to hardware failures.

Sometimes the behavior of software changes when passing from one release to another and it is needed
more than a simple recompilation of the in-house software to achieve the same response.

Discussion after the Conference:

Experiences with the Imagestation for Data Capture, by M. Torre

O'Sullivan:
It peaked my interest to hear that your operators can switch over within 2 to 3 days of training? Can you tell me the age range of your operators and also, what else did they learn during those 3 days training? plotting, model orientation and what else?

Torre:
The age range of our operators is from 30 to 33 years old. They have experiences on analytical plotters, but they do not have to worry about data management. This is a task that is being done by an engineer for he also sets up the models in the station. In our organization, we have 14 operators working on 7 work stations.

Kölbi:
I had the chance to see your organization once and I saw analytical plotters and digital work stations. Then how do you decide which operator is allowed to work on which instrument and is there a preference? Will you stay more in the digital side or will you stay half digital, half analytical?

Torre:
We do not have a preference of operators as to who should be working on the digital or analog work stations. At the moment, only 1 analytical remains in use. When you were there, there were 4 digital work stations and 4 analytical plotters; we now have 8 digital stations and only 1 analytical plotter remaining.

Colomer:
Yesterday, the issue of productivity came up. First, I want to inform you that we have tailored the data capturing environment according to our needs. It was refined a lot more than when you buy the actual data capture software. The screen setups, etc., those functions linking to the real time environment are a great help. The productivity after 2.5 years of production is more or less the same than with the analytical plotters, maybe even somewhat higher. One thing is the productivity in hectare per hour and the other is how much it costs. We have mainly saved in quality control. Operators can easily detect potential problems. I figured this saved us about 8% to 9% of the production time. The other savings came from the spare time in editing which is surprising. The private sector in Spain is starting to use digital photogrammetry for stereoplotting, but with low-cost systems like the International System Maps, which is PC based; they are probably more cost efficient than we are. It seems that everybody agrees that you spare 30%-40% in editing time due to the stereo super imposition. Of course, if you compare analytical with stereo super imposition like the P1 with Focus, or the SD3000 and let us ignore the question on stereo imposition, then probably the differences in cost savings would be in favor of the analytical systems.

Part 6

Logistics and Integration of the System

Direction :

J. L. Colomer J. Loodts R. Héno

Logistics and Integration of the System:
Experience at IGN France

R. Héno
Institut Géographique National - France

Summary

This short paper describes the workflows in a digital production line at IGN. The logistic aspects are specially emphazised.

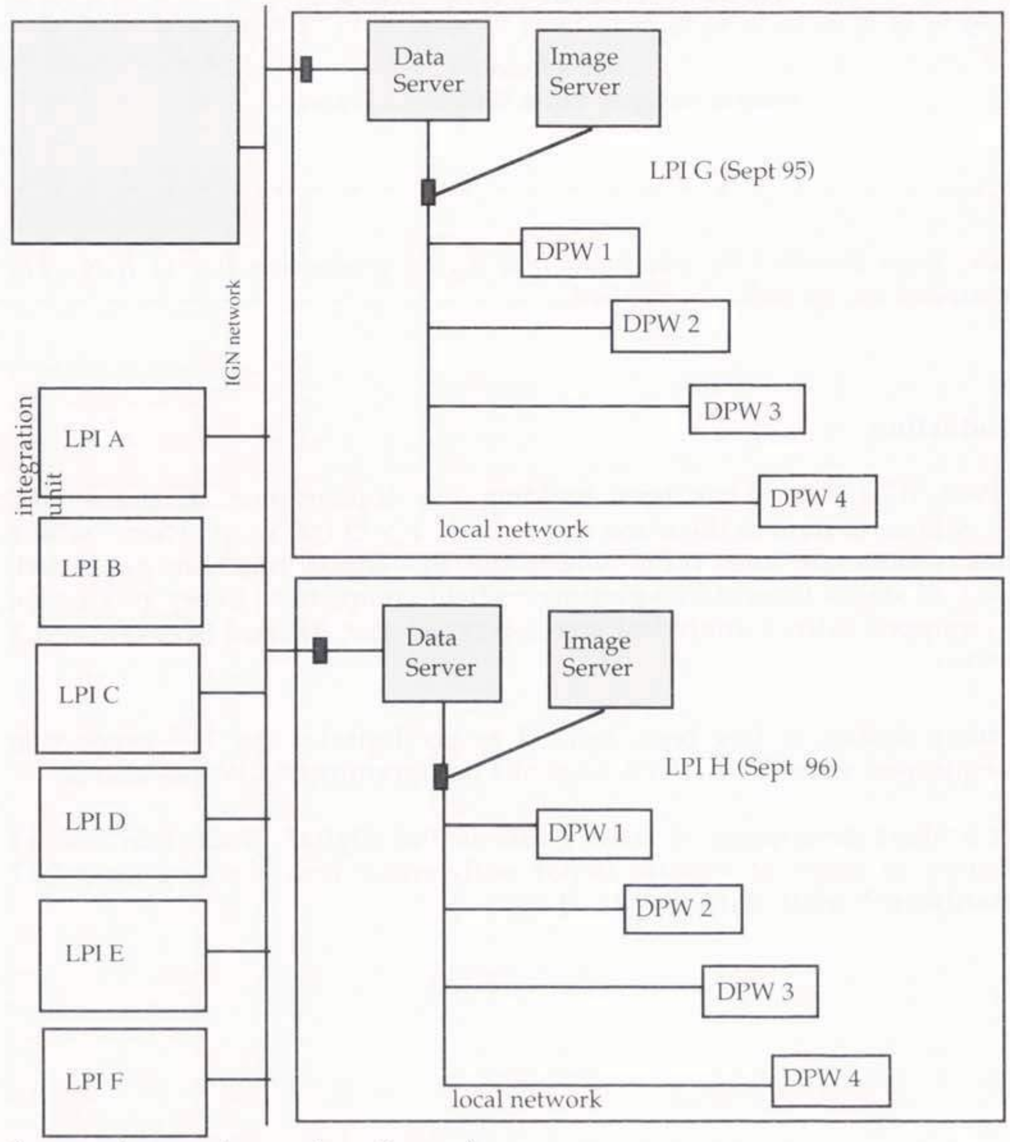
1. Introduction

Since 1986, IGN France has been building the topographic database (BD Topo®), whose content is the same as the basic 1 : 25 000 map. There exist 6 analytical production lines (LPI), where the BD Topo® units are generated, including all stages from stereo-plotting to field completion. Every production line is equipped with 4 analytical stereo-plotters (S9_AP and SD2000) and 1 data server.

After many studies, it has been decided to go digital : the 7^{th} production line is equipped with 4 HELAVA Digital Photogrammetric Workstations

Here is a short description of what exists in the digital production line at IGN France, in terms of logistic (what softwares ? how do they co-exist ? what hardware? what data flows...?)

2. Configuration of the production lines at IGN



(see next page for explanations...)

	hardware	softwares
Data Server	• SUN Sparc 20 64 Mo RAM 3 Go Solaris 2.4 • Exabyte backup drive	GÉOCity server (Clemessy - France)
Image Server	• SUN Sparc 20 32 Mo RAM 16 Go Solaris 2.4 • CD Rom reading device • screen steroscope	SOCET SET (HELAVA -USA)
DPW 4	• SUN Sparc 20 64 Mo 2 Go • CD Rom reading device • polarized screen • handwheels	SOCET SET mono GÉOCity client GÉOStéréo (Syseca - France)
	• Ethernet 10BaseT	
LPI A	analytical production line (equipped with 4 analytical stereo-plotters and 1 data server)	
integration unit	integration unit (see §4 for a description)	

GEOCity is a GIS (Clemessy - France), SOCET SET is a photogrammetric software (Helava - USA), and GEOstereo (Syseca - France) is an interface between these two softwares used for data capture. There are also home-made programs, used mainly for data-management, or image processing.

3. Data flow in a digital production line

Changing to digital photogrammetry must not be a charge for the operators. Thus, it has been decided to provide them with ready-to-use images. The preparation is done on an image server, by a single operator who must be familiar with computer handlings. Of course, those handlings should be as simple as possible. Making the process simple can be achieved with an open development platform, where tools can be easily devised and integrated.

As far as IGN is concerned, real-size production has started only very recently ; there are still some tedious steps to perform all along the process. Many tools are under developpment, that should make the life of the staff easier.

3.1 What is being done...

Outside the production line :

stage	characteristics	output
traditional aerial survey	• 1 : 30 000 • B&W	50 films to produce a BD Topo unit
analytical aerotriangulation		50 PUGed films with terrain point files
scanning	• raw format • pixel size = 15 μ • no compression is done yet	50 images stored on 25 CD Rom

On the image server :

Images are processed strip by strip on the image server. There are 12 or 13 images in a strip. As soon as a strip has been used, the images are removed from the image server, and a new strip is processed. The parameters files containing the orientations parameters are carefully archived with the CD Roms.

stage	characteristics	output	duration
project preparation	• definitions • importation of ground points	1 HELAVA project done	5 mn

stage	characteristics	output	duration
image loading		1 strip of images stored on the hard disk of the image server	12 mn/ image
image conversion	• from raw format to any HELAVA format	1 strip of images in the HELAVA project	5 mn/ image
image minification		1 image pyramid / image	3 mn / image
inner orientation	• semi automatic		30 mn / strip
outer orientation	• it does not require any measurement thanks to an home-made program which converts film coordinates of ground points (coming from analytical aerotriangulation) into screen coordinates	1 strip of images properly oriented.	10 mn / strip
image processing	• including correlation for automatic Z extraction (still under development), epipolar resampling and image enhancement (not systematically)	• DTM • epipolar images • enhanced images	variable
image delivering to the 4 DPWs through the local network, according to a rigorous planning		every digital stereoplotter is provided with ready-to-use images.	7 mn / image

On the data server :

stage
project preparation
miscellaneous preparations (mainly S9 edge data import)
controls
draft plots

On the DPWs :

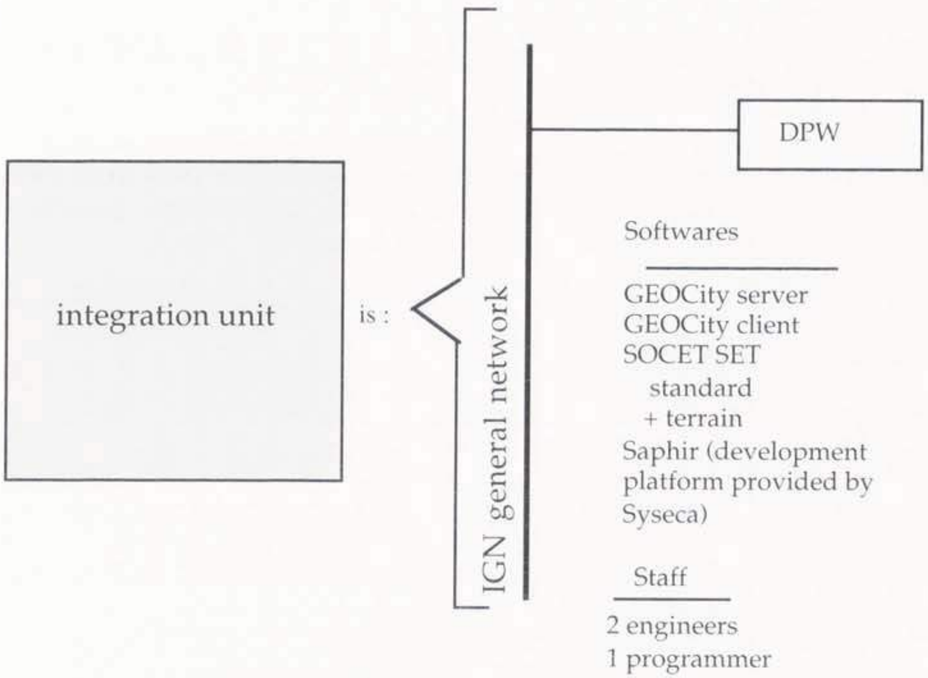
stage	output
stereo-plotting	
controls	controlled and edited data

3.2 What is expected to be done in the near future...

Aerotriangulation will soon be done digitally. Most of the elevation features will also be soon automatically extracted. The data flows will then change slightly into :

- traditional aerial survey
- scanning
- image loading to an image server
- image conversion
- digital aerotriangulation
- image processing (including DTM extraction, and maybe DTM editing)
- image delivering to the DPWs
- stereo-plotting

4. Description of the integration unit



4.1 Main purposes of this unit

This unit is supposed to be a bridge between the resarch departement of IGN and the digital production lines.

This unit will be specifically in charge of :
1 - defining a process for digital updating
2 - defining integrated tools for image processing, and image quality assessment
3 - defining a tool for managing disk space
4 - defining processes for automatic terrain extraction and integrated tools for DTM interactive editing.

Without disturbing the production planning, this unit will design robust and integrated tools so that the production lines can take fully advantage of the digital photogrammetry.

5. Conclusion

We, at IGN, daily realize how important it is to work with a well-chosen hardware, and a rigourous organization.

The main reasons why we are already satisfied with our process (even though it is not finalized yet) are the following ones :

• the images are processed strip by strip on an image server, without disturbing the operators.
• the images are distributed from the image server to the stereo-plotter through a local network (ie. not the general IGN network).
• the images are safely archived on CD Rom

We plan to keep on automating the process, especially the part concerning disk space management. The deeper exploitation of the various aspects of digital photogrammetry should benefit from the time thus spared.

Discussion after the Conference:

Logistics and Integration of the System: Experience at IGN France, by R. Héno

Eidenbenz:
What is the minimum and maximum time you need to plot a complete model?

Héno:
For a complete model, we need one to five days, it depends.

Eidenbenz:
Do you still capture the heights of the houses and the third dimension of the houses?

Héno:
We measure 4 points of a house and the four corners of the buildings. There is no automation in that process yet, but I think the algorithmic part will soon be available.

Heimbürger:
How do you organize the system and the data back-up for the digital work stations?

Héno:
We use Exabytes for the back-up. When one DB unit is finished completely, we also store the data on optical disk. It takes roughly 2 months to plot 1 DB unit. We back up every day on Exabyte, but only when the project is finished and controlled, then it is stored in a safe back-up device.

Everaerts:
Is there any reason why you are using image and ground coordinates and not parameters from the aerial triangulation for your absolute orientation?

Héno:
Because we are not sure if the models used for orientation are the same. Actually, we are sure that they are not the same.

Logistics and Integration of the System: the ICC Experiences.

J.L. Colomer

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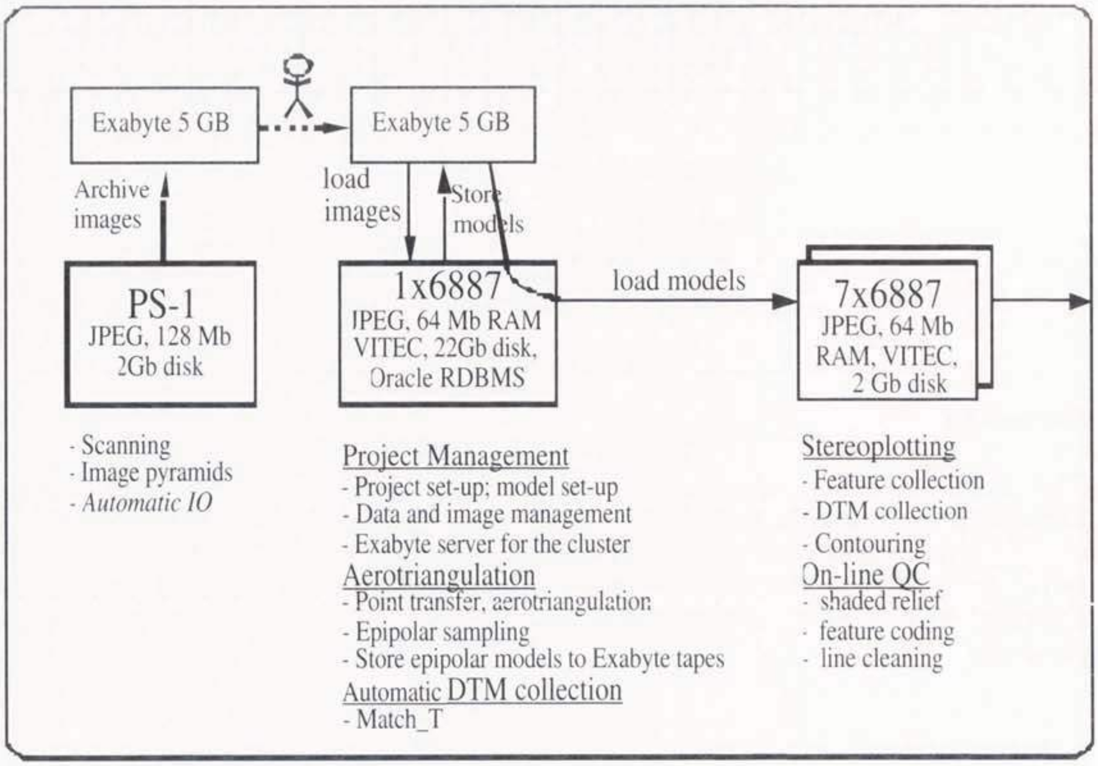
Summary

This short paper describes part of the methods and workflows of the Institut Cartogràfic de Catalunya from an operational point of view. The concept of workflow automation and project management is justified, and the intensive use of batch techniques is discussed. Finally, some of our internal developments are described and current data on reliability, maintenance and internal support are presented.

1. Introduction

The goal of logistics is high throughput at a reasonable cost. High throughput can be achieved by using high performance hardware and software, but also by setting up smooth and efficient workflows. A smooth workflow means that neither an operator waits for data, nor a batch process gets canceled because of lack of resources; it also means sparing unnecessary and repetitive operator actions as much as possible. Proper resource allocation, capacity planning, performance evaluation, scheduling and workflow optimization also belong to logistics. These issues become increasingly important as the environment gets larger.

Practical solutions are site, system and project dependent. The system features, the site size and specific policies and methods do not lead to universal solutions. This paper describes our practical experiences working with the Intergraph based environment shown in the figure below. The paper focuses on integration and optimization issues rather than on hardware and software aspects.



2. Data management

At current market prices any system can be configured with enough disk at a reasonable cost. Enough disk space means less data management because of fewer file allocation demands. In this respect, image compression is a real help.

Scanning

We normally scan at 15μm for B/W images and at 30μm for color. The average compression factor achieved is around 4x for B/W images. We have done around 4500 scans in 1995 and 8000 are foreseen in 1996 for stereoplotting and orthophoto. This is a good amount of files. Therefore, it is important to establish and maintain a meaningful and robust file-naming convention. Our current one is based on a combination of the flight number, the Spanish base map number, and the strip and photo number.

Scanning is not synchronized with any other production process (a very common practice here). Rather, photos are scanned independently as soon as possible and filed for future use. The generation of image pyramids needed for semiautomatic point transfer is part of the scanning process. Exabyte tapes are used for filing and as buffer for eliminating the impact of the current 5% downtime of the PS1 (including planned upgrades and calibrations). The tapes are finally catalogued and kept permanently in the central filing facilities of the ICC.

One can certainly argue against filing the images permanently. Among other reasons, our main motivation is future: we believe that our traditional customers that use photographic copies and enlargements from our aerial photo archives will start shifting from analog to digital in the next few years.

Digital point transfer and aerotriangulation

The aerotriangulation workstation has enough disk space for holding a complete block of input images with image pyramids. Our average aerotriangulation block has around 150 photos, but dealing with larger blocks is not so unfrequent. Images are loaded from the image archive via Exabyte. After point transfer and aerotriangulation we launch epipolar sampling in batch. The models are stored on Exabyte tapes stripwise (only one strip per tape) and deleted from the disks. The Exabyte tapes are used temporarily as buffer storage for the duration of a DTM or stereoplotting project, and are never catalogued in the central storage facilities.

Stereoplotting

On demand, the stored models are downloaded to the stereoplotting workstations over the Ethernet using the Exabyte device of the server workstation. Afterwards, we run a utility to change the data path that is hard-coded in the model control files, since it is the one specified during the epipolar process, but not the actual one in the stereoplotting workstation. The same applies if one moves a model from one disk to another.

Comments

In total, there are four manipulations with Exabyte in our workflow. This means that the tapes must be mounted, a save utility launched, and that a label with the index of contents must be physically attached to the volume. Each file is its own save set. This allows to position the tape at file "n" within (n-1) minutes instead of (n-1)*6 minutes if all the files are in the same save set. Of course, the replacement of Exabyte tapes by rewritable optical disks would make data storing and retrieval much quicker.

Another option to consider is a system-wide image and data server with some type of hierarchical data storage system and managed by the central computing facility staff. We could then use it both as archive and buffer storage, thus avoiding the operations on local devices. Of course, high reliability should be guaranteed. The increase of Ethernet traffic would probably not represent a major problem. So far, we maintain acceptable performance levels by segmenting the Ethernet and by denying the transfer of image files larger than 1MB between non-production workstations.

3. Processing

Interactive tasks and batch applications do require a short turnaround time. There are also real-time functions that must have a response time below one second. Large data sets combined with the increasing complexity of the algorithms are sources of processing bottlenecks. Therefore it is advisable to monitor and tune the systems, particularly paging and disk IO activity. Again, image compression helps here in reducing the IO traffic. If results are not satisfactory, there is nothing else to do other than buying a faster system or trying to tradeoff accuracy for throughput.

Batch is used for processes that last too long for an interactive session. In our digital photogrammetric environment (including the own developed orthophoto system), batch queues are used for:

- Epipolar sampling & image pyramid:	2*23' with 15µm/pixel B/W
- Match_t automatic DTM generation:	35' (30µm)
- Orthophoto rectification:	5 Mpix/min B/W; 1.7 Mpix/min color
- Orthophoto image processing (color):	0.9 Mpix/min (color and mosaic)

Reducing interactions

In preparing jobs for batch processing the user interacts with a GUI for data entry and parameter setting. Afterwards, the software generates a shell script that is submitted to batch queues.

Note that, for a given project, there are some parameters that remain always fixed, and that some job sequences are repeated again and again. For example, the only part of the epipolar sampling that is not already defined by the project engineers is the output file path and the (seldom used) possibility to define the output model extent, which is always defaulted to the entire model area. Since parameter values are decided at the start-up of the project, it would be useful to store and retrieve them for generating the shell scripts automatically. Note that, as a rule, we do not allow the operators to change defaults while in production: difficult cases are solved by engineers. Should the operators modify parameters, we would then advise to save them on the file header or somewhere in the control files for control and tracking.

There is a further example, namely the operator's suggestion to do an automatic inner orientation and to include it in the scanning job step. Strangely enough, the Intergraph point mensuration software does already provide an excellent GUI and image matching tools for measuring the fiducials. Nevertheless, it seems that our operators want to spare as many interactions as possible.

One step further: the project database

The concept of project management also belongs to logistics. That is, keeping track of the events in a project: degree of completion, project wide defaults, parameters and options used, error reports and accuracy figures, etc. The goal aims, first at reducing the project management staff by providing a "project database" created at the project definition stage and constantly updated by the processes and, secondly, to enable batch automation by having the programs retrieve the project wide parameters from the project database, thus reducing operator interaction to a minimum. The penalty to pay is a somehow longer project start-up time and a quite rigid workflow once defined.

We have now been working with such an approach for almost eight years for digital orthophoto production (Colomina et al. 1991), which is the simplest digital photogrammetric workflow to deal with. With a current throughput of 50 B/W orthophotos rectified daily, the approach has proven to be a very efficient way to run projects with a minimum staff. As mentioned, the programs access the database for retrieving parameters and for updating the status. The database is also used by the automatic scheduler which, among other things, does resource allocation and tracking. Status listings can be obtained straight away from the database.

In the present Intergraph environment there is a network wide utility to store/load photogrammetric photo and control files to a relational database. Using this mechanism, the fixed path inconvenience mentioned before is completely solved. We are quite sure that this facility could be used to provide workflow automation. Unfortunately, no single processing software uses the database yet. The Image Index mechanism implemented recently might be a first move in the right direction.

Summary

In summary, we would advocate for an environment with a file system with advanced data management and space allocation tools. UNIX is probably not the best operating system to provide such capababilities[1]. For the user interface, we would propose to have two components: the standard "verbose" GUI for novices, testing and special cases, and some type of customizable environment for automating workflows and for managing projects.

4. Integration

The integration of applications is a key issue for efficiency. The goal is to ensure that workflow never loops back. This means that appropriate tools

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1 As far as the author is aware, automatic file naming and allocation are used by the Zeiss SCAI scanner. This enables to scan, do image pyramids and perform the interior orientation unattended.

shall be available at the operator's site to make sure that the data passed forward are completely correct. This is specially important in a photogrammetric environment if one considers that editing workstations do not have 3D capabilities (editing 3D data on a 2D workstation has proven to be very dangerous, even with firewalls against mishandling).

Right now, we are starting to evaluate the integrated DTM tools provided by the Intergraph DTM data collection software. We are also studying the possibility to integrate some basic GIS functions for line cleaning and topological checking within the stereo workstation environment. In general, one might classify the integration levels as follows:

- low: the operator exits the stereoplotting session and starts another application; data are passed forward by an explicit import operation involving re-formatting data
- medium: the same as before but without the re-formatting
- high: the integrated application accesses or shares the data structure already stored in memory by the photogrammetric data capture application (i.e. editing an elevation point dynamically changes the contour).

Ideally, a digital photogrammetric environment should borrow the idea of "component" from the software engineering community, in the sense of allowing the developer to customize a new stereoplotting application based on a functions library.

We shall also make a strong point against unnecessary pre-processing steps. Among them, re-formatting takes a good deal of time. Given that re-formatting is unavoidable for importing external data and that proprietary formats might be more efficient, there is no excuse to have incompatible data formats across applications from the same vendor.

5. Development libraries

After some time users start using the system in a way unforeseen by vendors. Some ideas discussed previously are examples of this trend, at least at the ICC. The user may be willing to integrate its own software and procedures to enhance or customize the system to specific needs. Therefore vendors should provide an open, consistent and well-documented development interface. Documented data formats and macro capabilities belong also to this open environment. Besides the workflow oriented enhancements discussed in this paper, we can classify user development as follows:

- Development of core functionalities affecting the real-time behavior of the workstation. It involves linking with the real time core software, and this is difficult and error prone. We have done this only once with a lot of support from Intergraph.

- Developments aimed at customizing a data capture environment by developing macros and menus and/or by integrating own developed functions. The main difficulty here is to access the data structure in memory if a high level of integration is wanted. Besides the µStation development language (widely used for customizing the data capture "menus" at the ICC), Intergraph provides "development platforms" to help the user in developing own applications. So far, we have used the DTM set of routines. The image processing/photogrammetry development interface has not been used yet.

6. Maintenance and support

Last, reliability, availability and serviceability belong also to logistics. Because the digital photogrammetric stereo workstations are based on computers, one must be ready to have hardware and software problems. The downtime represents now 2.3% of our working time (0.5% is due to hardware failures). During the same period of time, the analytical systems had a 1% downtime.

Against hardware failures there is nothing to do but to contract the maintenance service offered by the manufacturer, specially if the system uses proprietary hardware. Note that the big advantage of PC-based systems with standard graphic components is the possibility to build up a set of spare parts that can be replaced immediately by the user. Downtime can be classified in the following categories:

- Hardware failures leading to a complete halt
- Occasional errors requiring to reload the software or rebuild the file system
- Occasional errors requiring rebooting (real-time conflicts in the core software)
- Reproducible application software bugs (hopefully detected and solved before going into production!)

The categories above match our internal support structure. Product installation and operating system maintenance are supported by the Computer Systems Department; core software and workflow integration/optimization by a senior engineer. The support averages now half a person/year. Data capture applications are developed by the Automatic Cartography Department, which is specialized in µStation and Intergraph GIS products. Digital point transfer products are the responsibility of the Geodesy and Surveying Department.

7. Final remark

Recent studies of the Information Systems community show that the complexity of managing client/server environments increases geometrically as components are added. The complains are about performance monitoring and management, problem resolution, software distribution, job scheduling, capacity planning and storage management. It has been often mentioned that low cost digital photogrammetric stereo workstations would spread the use of photogrammetry. At the ICC, the geologists and land-use photointerpreters are eager to use the stereo capabilities offered by photogrammetry. Are current photogrammetric systems ready for this growth?

8. References

Colomina, I., Navarro, J., Torre, M., 1991. Digital Photogrammetric Systems at the ICC. *Digital Photogrammetric Systems*, Wichmann, Karlsruhe, 217-228.

Discussion after the Conference:

Logistics and Integration of the System: The ICC Experiences, by J. Colomer

Kaczynski:
What methods do you use to re-boot when you have problems with the Intergraph software?

Colomer:
It is very easy, we call Margarita Torre and she either solves the problem or calls Huntsville, U.S.A directly to speak with the developers. Of course, for re-booting, we literally just press the button.

Becker:
You mentioned a 2.3% downtime, what about the actual production lost? Do you lose the data when re-booting?

Colomer:
Data loses are not part of digital photogrammetry, but of Microstation, it is their problem. The way I calculated the production loss is by multiplying the percentage by 15 hours per day, so you get more or less the hours lost for production per day per work station.

Becker:
What I mean is if the system crashes at the end of a 3 hour process, have you lost the 3 hours work? Maybe you only have 2 minutes idle time once you re-boot the system, but you have lost 3 hours.

Colomer:
Normally, this is not the situation with the Microstation. Microstation stores every record on the disk; figuratively speaking, it is like a straight-through strategy. If we re-boot, we normally do not lose the data, but of course, anything can happen, you never know.

Adam-Guillaume:
I would like to say that we back-up frequently, but I find that it is not enough. If you back up at any stage of the job, not only speaking for plotting, but also for all the image processing and so on then you spend time just on backing up. There are other problems also, for instance, my company moved to bigger offices last year. The systems were re-installed improperly and it took three weeks to fix I; therefore, we lost a considerable amount of time and money due to network problems. In addition, for lack of room on our disk, we have to make a back-up and we know that in one month, we will have to re-load those back-ups again. Some of our clients have different support devices so we have to support them with 6 different output devices, such as Syquest back-up, for example. The other issue is about formats. We lose a lot of time because most formats that I use for geography are not designed for

geography. Let's take DTMs as an example; our clients want a format for it and there is no real format. In order to accomodate our clients, we adopted a format that has been proposed by IGN for Raster DTM. But what we would like is a more simple format with raster data, a header and on that header, only relevant geographic data and we would be happy to comply with that format. At the moment, you give us your format, we will emulate it and of course, it takes time. Production involves development which is very heavy. About hardware failures; I do not know other people's experience, but I think UNIX stations have less problems than PCs. We have a lot of problems with PCs. Although one great advantage of a work station is that, at the moment, there is no known virus in UNIX yet. In any event, I would say that overall, our downtime is much higher than 2.3%.

Colomer:
Although we have our own format for image and DTM, you are absolutely right that format conversion is a nightmare and a waste of time because you are just reading and writing. The second thing is, I agree that UNIX work stations are more stable than PCs; though VAX stations, the older technology, I think was still more reliable. By the way, Ethernet can also be a problem. Then we have this problem of backing up. We adopted the normal information technology strategies for backing up over the network. This is done over night from the computer center. However, every development group, especially when he designs the work flows, he decides which sensitive data must be saved immediately. So at the moment, the probability of losing data concerns the production of half a day at ICC.

Eidenbenz:
Did you consider the downtime coming from unmotivated operators and coffee breaks? And what about the regulation that I think might be coming up in the European community? If you are working in front of the screen you have the right to have a break for 10 minutes per hour. This new regulation, if passed, will definitely give you more downtime than the downtime you mentioned.

Colomer:
We are an autonomous governmental agency, therefore, we get a little bit more flexibility. The operators get more money if they are productive so it is up to them. Concerning the new regulation that might come up; in a 7.5 hour shift, they have a 20-minute break which is only taken once during one full working day—not 10 minutes per hour. We are definitely not complying with that rule.

Holmes:
We have two 15-minute breaks and we also have to have a 30-minute meal break, but you cannot work for 7.5 hours without a meal break, it is just not allowed in the U.K. You cannot count this as downtime because they do not record meal breaks.

Logistics and Integration of the System: the Eurosense Experiences

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Summary

The first part of this paper gives an overview of the functionalities of the present digital photogrammetric workstations (DPWs). A special emphasis is put on data exchange between different DPWs and on how to open the system.
The second part deals with the problems of large-scale digital terrain models (DTMs). Our solution consists of a macrolanguage with a link to a GIS.

Introduction

Since many years, and especially since the last ISPRS congress in Washington DC (1992), a lot has been published on DPWs and on the possible links with GIS. However, we still live in a world where photogrammetry, GIS and image processing are separate disciplines - and what is even worse, there are no signs that a possible integration is at hand.
At present, digital photogrammetry is essentially used to produce automatic DTMs and large and medium-scale digital orthophotos. The main criticism against the automatic DTM algorithm is the use of uncontrollable (even 'magic') strategies and the use of regular grids. As a consequence, the editing phase cannot be avoided to check the results, and the DTM mostly needs local corrections.
The large-scale automatic DTM quality is even poorer! At large scales, the difference between DPWs and analytical stereoplotters ceases to exist: both DPWs and analytical stereoplotters are used in the same way, and they function the same way.
In what follows, we will illustrate an open DPW by the information contained in the digital images.

A. DPW Functionalities

Functionality	*Helava DPW770*	*Intergraph ImageStation*	*Vision Intl. Softplotter*
1. Internal Orientation			
1a. Automatic Internal Orientation			Y (not working?)
1b. Import Export Transformation Matrix	Listing	Listing	Listing
1c. Fiducial Coordinates	Listing	Listing	Listing
1d. Geometry Check (resol/Nb pixel)	N	N	N
1e. Batch command for Automatic Internal Orientation			N
2. External Orientation			
2a. Import XYZ,Omega,Phi,Kappa	manual		Y
AT formats	Albany manual	Albany PAT Bluh	Albany PAT JFK Generic
2b. Export XYZ, xy (pixel)	Listing	Listing	Listing
XYZ, xy (micron)	Listing	Listing	Listing
Tranformation Mat	N	N	N
2c. GCP Visualization if Orientation exists	Y		not in orientation tool
New GCP Visualization	Y		N
2d. On derived image or from other system			N
2e. Pyramid (Long processing time)	Y	Y	Y
2f. Batch function			Y
2g. Automatic Quality Control GCP vs. Orient	N	N	N
3. Stereopair (epipolar images)			
3a. On derived image or from other system			N
3b. Pyramid (too long process)	Y	Y	Y
3c. Import Export image coordinates	L	L	L
Transformation Mat			
XYZ -> xp (pixel/micron)	L	L	L
3d. Visualization GCP	Y		N
point feature (DB)	(Y)	(Y)	(Y)
linear feature (DB)	(Y)	(Y)	(Y)
3e. Terrain following by correlation			Y
Using DTM			Y
3f. Batch generation		Y	Y
4. Image Processing	Simple	Simple	External

Table 1 - Overview of DPW functionalities
N: not available
Y: available
L: listing

5. **Missing features**

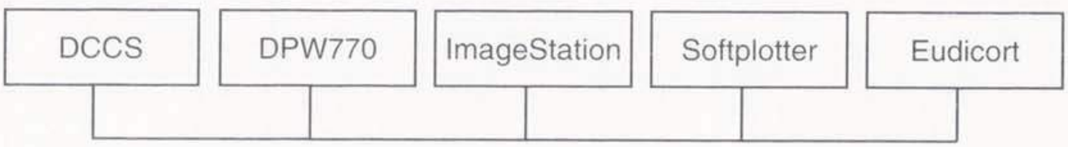
5a. No executables for a set of functions, i.e.:
- Image correlation for a predefined set of points
- Feature extraction
- Output of interest points (where applicable)
- etc....

5b. No line following

5c. No quantitative quality check with existing data; vector superposition exists but there is no quality check at some points.

5d. Before orthorectification: no way to list the errors in planimetric coordinates such as (X,Y,Z)gcp, Zcomp, (xy)p, (xy)ortho

5e. Data exchange between different DPWs:



Only 3 standard ASCII files with Internal , External , Epipolar matrix transformations are needed

5f. Batch processing should be further developed: macro language?

B. Description of a DPW with a macro language

- Environment: ARC/INFO
- Macro language: AML
- Stereo display: Anaglyph
- All functionalities are menu- and command-driven
- It is a DPW with a direct link to a GIS
- This link is not only justified for a direct access to a DB but mainly for the ability to use spatial modelling and spatial analysis tools
- Real interaction between raster and vector data is finally possible
- One or many vector layers may be superimposed on one image
- Multiple windows may be generated with different vector layers
- Thematic or spatial vector selection is allowed
- For each window different display modes are allowed : stereo, mono or 3D
- This DPW works as a monoplotter or as a stereoplotter
- Digital stereo orthophotos are automatically included in this DPW

Photogrammetry delivers object restitution in three dimensions. GIS data are still twodimensional data. Therefore, photogrammetry can be a driving force to integrate digital terrain models, to develop three-dimensional data structures and to visualize in 3 dimensions by means of drape facilities.
Feature extraction and feature-based matching techniques are certainly much more advantageous for DTM reconstruction.
Area-based matching techniques can still be regarded as a useful complementary matching tool to improve the point precision wherever necessary.

C. List of figures

Figures 1 to 5 show the same portion of a colour stereopair after epipolar transformation. The upper image represents the right component of the couple, the lower image represents the left component.

Fig. 1: the red channel
Fig. 2: a transformation of the red channel
Fig. 3: a set of points extracted from the red channel
Fig. 4: a Voronoi tesselation created with the points of Fig. 3
Fig. 5: a set of breaklines extracted from the tesselation

Fig. 6: the lower image represents the resulting automatic DTM with superimposition of breaklines
Fig. 7: a 3-D reconstruction of the image portion

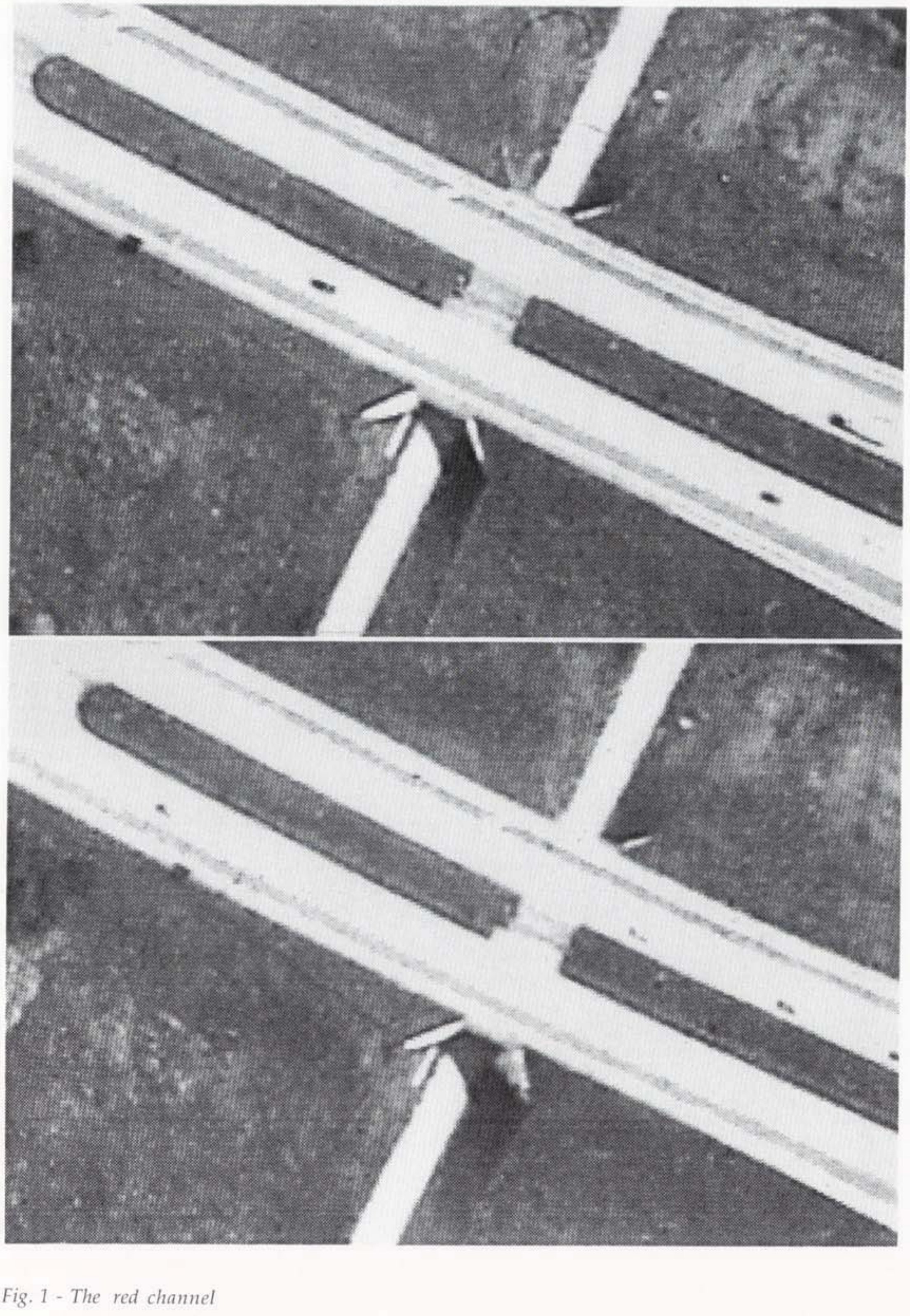


Fig. 1 - The red channel

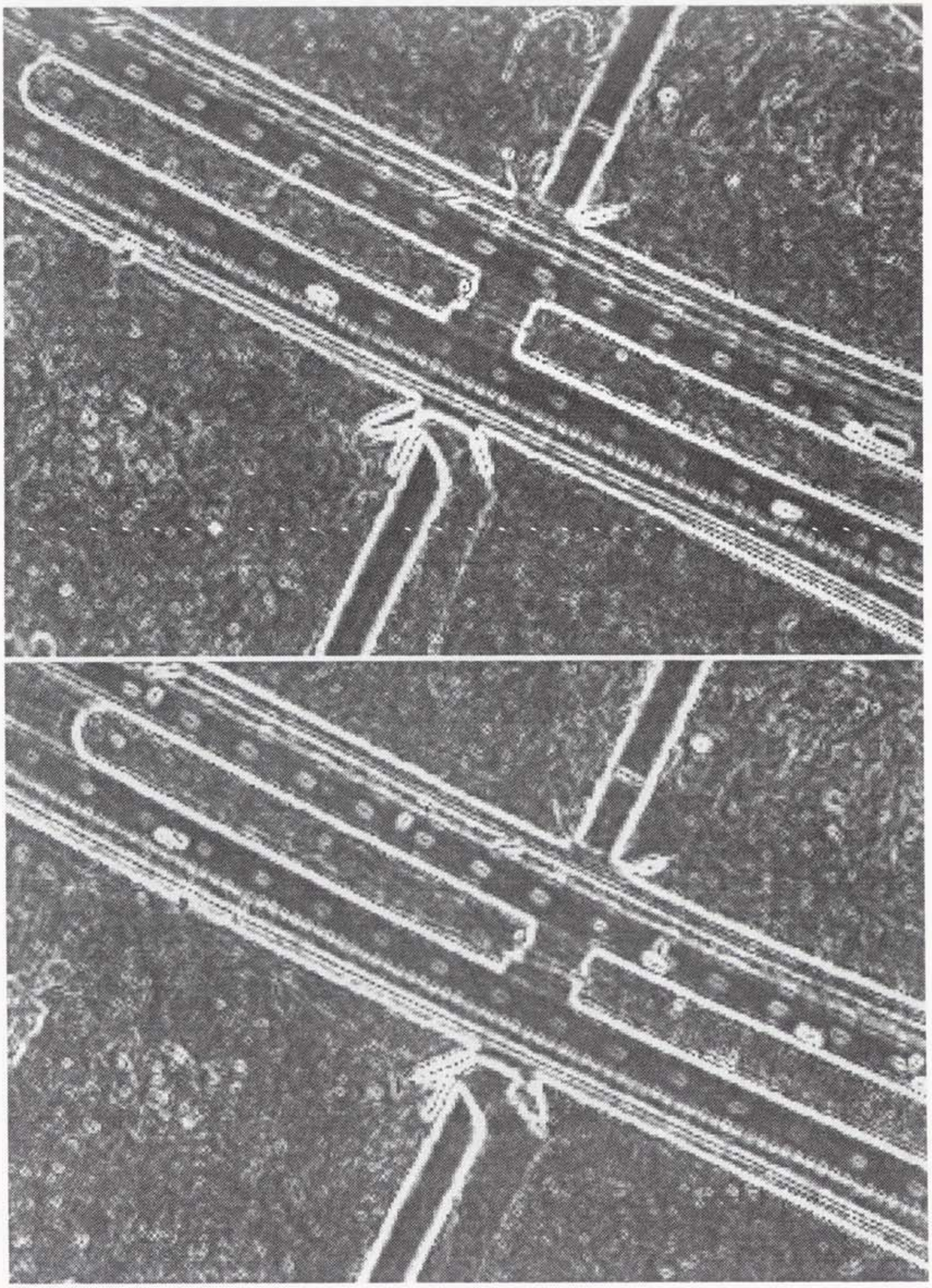


Fig. 2 - A transformation of the red channel

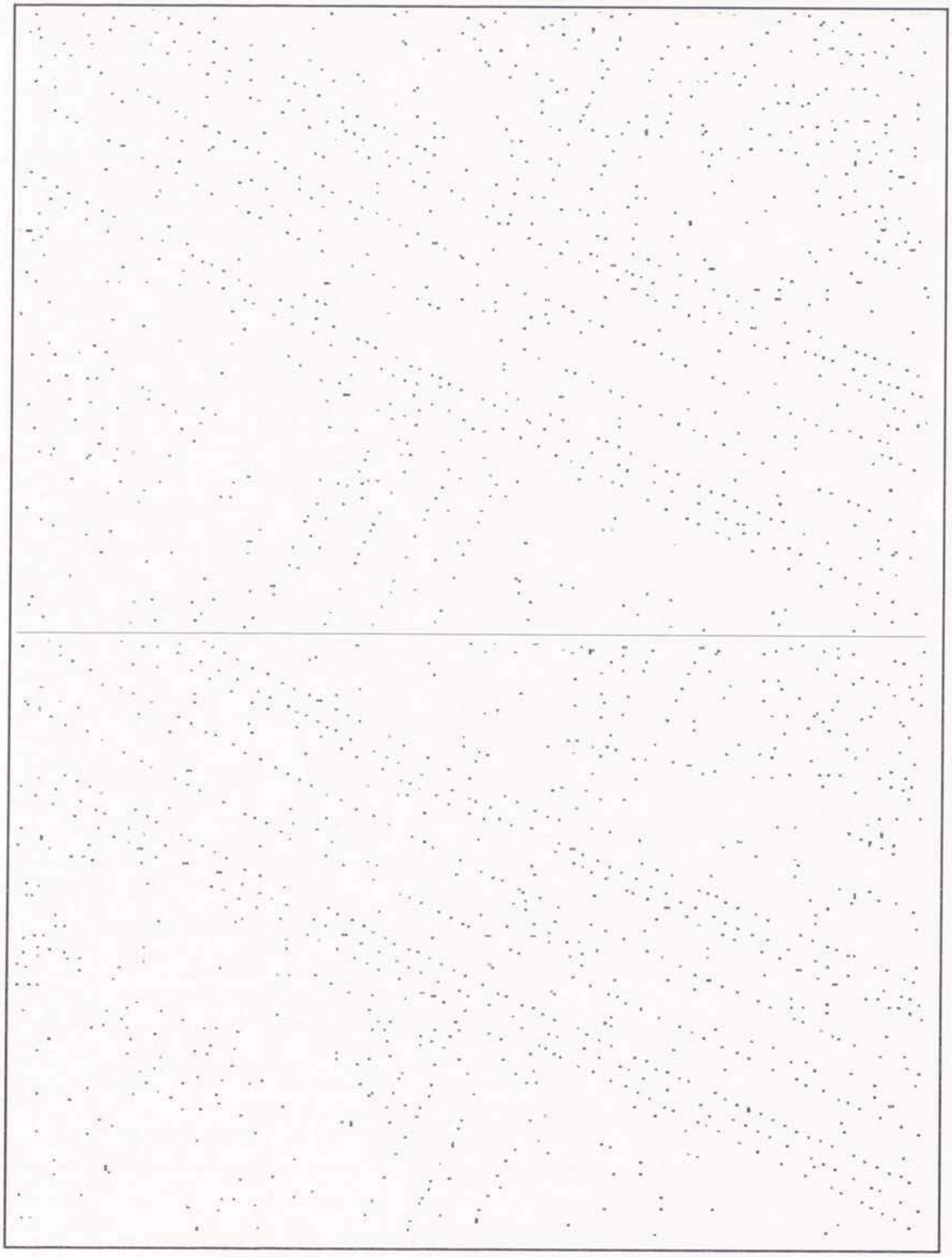


Fig. 3 - A set of points extracted from the red channel

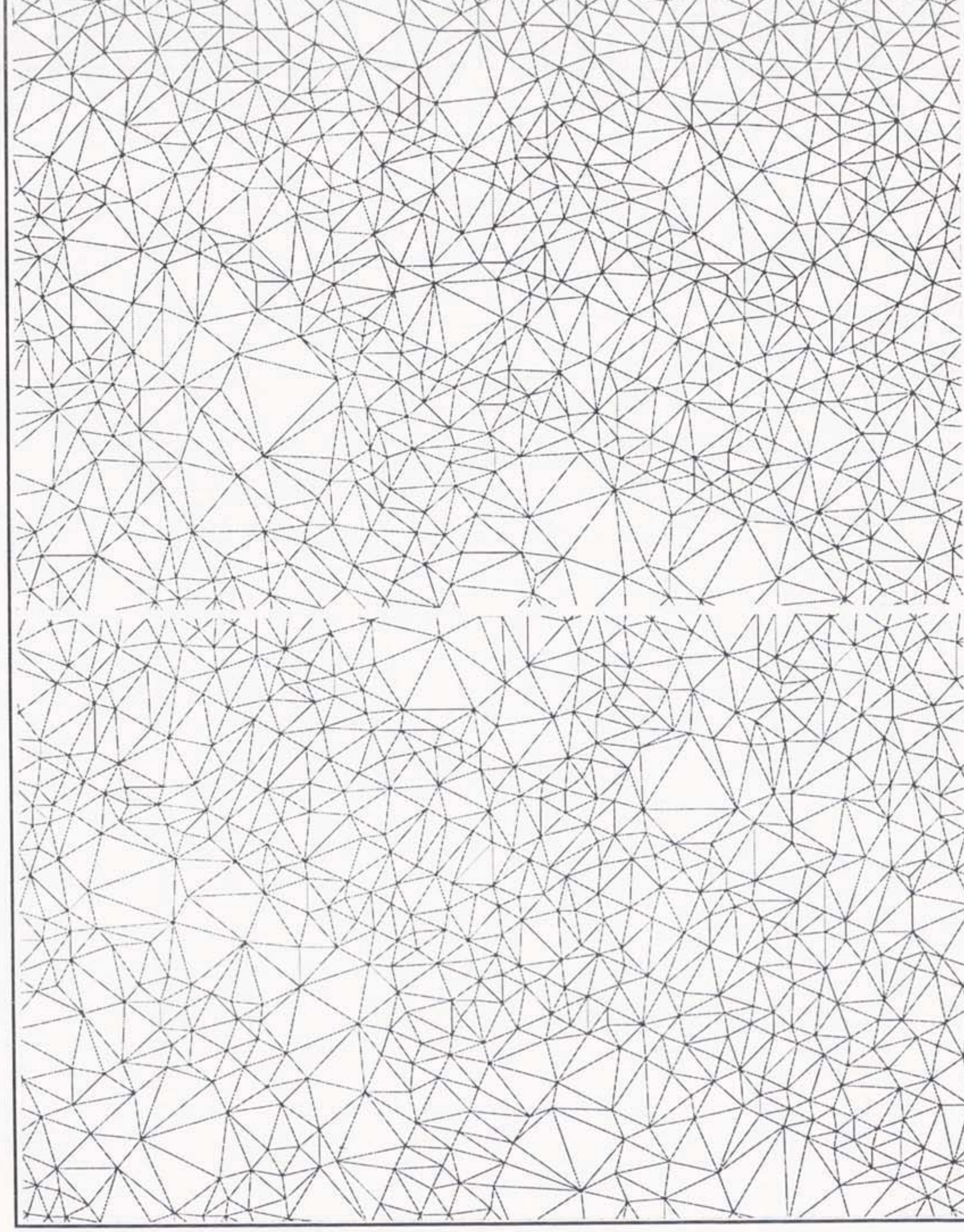


Fig. 4 - A Voronoi tesselation created with the points of Fig. 3

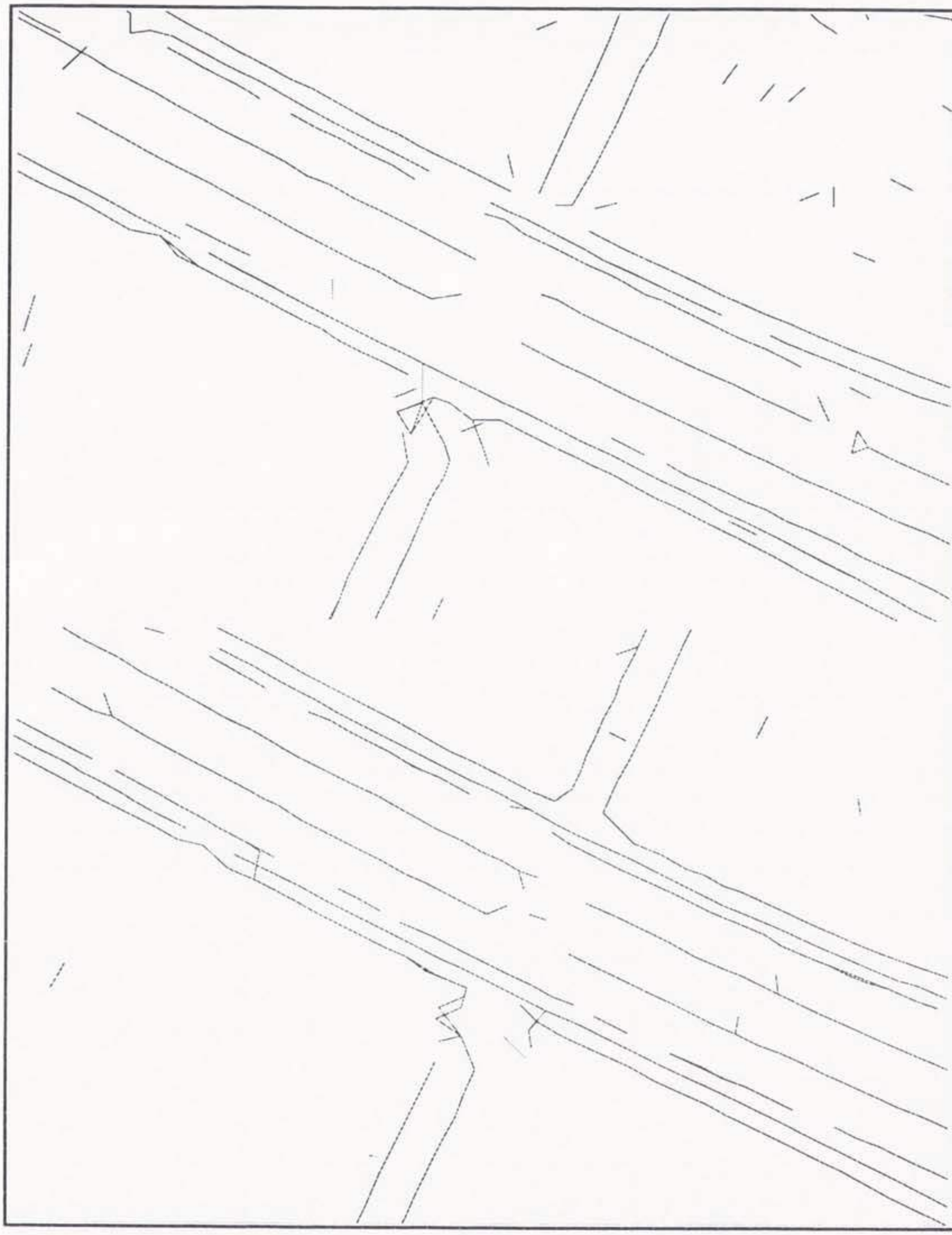


Fig. 5 - A set of breaklines extracted from the tesselation

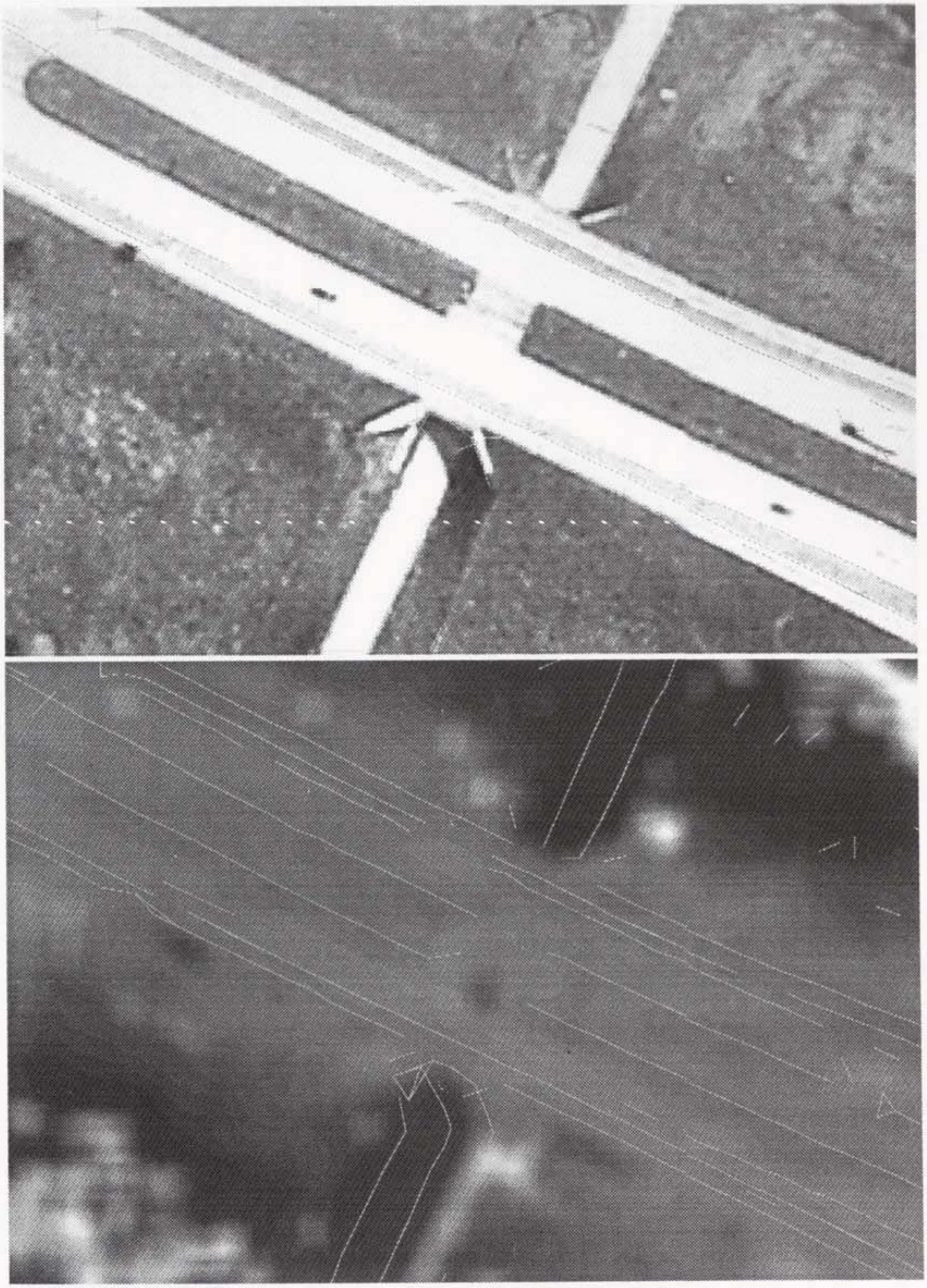


Fig. 6 - The lower image represents the resulting automatic DTM with superimposition of breaklines

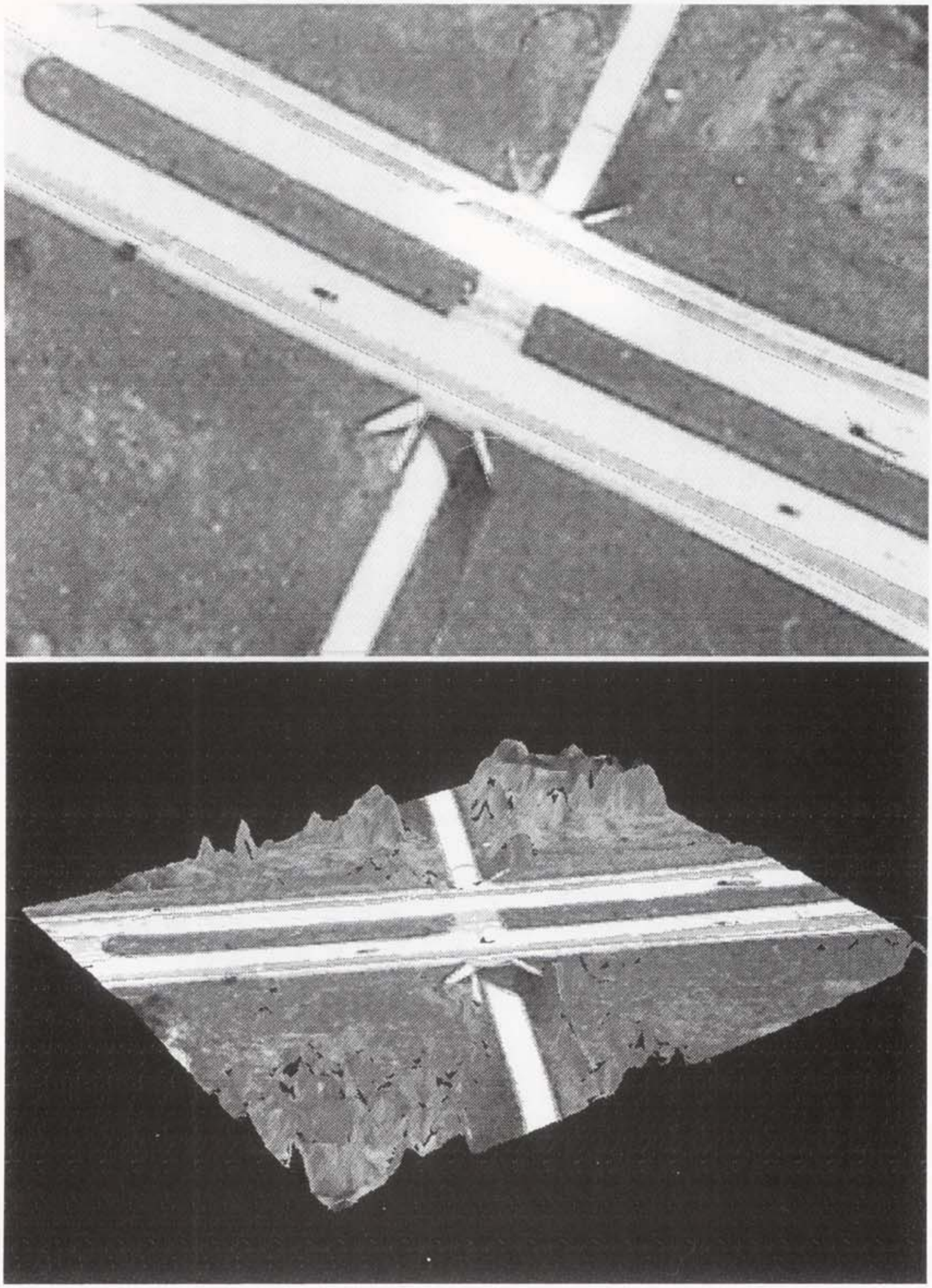


Fig. 7 - A 3-D reconstruction of the image portion

Discussion after the Conference:

Logistics and Integration of the System: The Eurosense Experience, by J. Loodts

Roth:
You made a lot of runs through different systems to find out which is the best one for your large scale DTM that you want to generate. My question is, because you did not say anything about the amount of time necessary to obtain the different results, can you then give us some figures?

Loodts:
We are using ArcInfo just to build up the algorithms. I do not pretend that these algorithms are efficient. The orthophotos that I made with this utility took 5 hours in the beginning. Now that the utility is refined, it only takes 15 minutes to treat an image of 16'000 x 16'000 pixels with 24 bit. But the idea was to show that we need integrated image processing, we cannot separate GIS and photogrammetry. We can solve a lot of problems, also specific large scale problems if we only have good tools: a good software library, and a good micro language. These are the basic requirements which come up and we absolutely need these things. How to open a system might be a nightmare, but we need to open the system; we cannot use a system which is only dedicated to special objectives like the analog system at the time. For example, a module for correlation, like in Helava, Intergraph, or others, they are too dedicated. As an example, if there is a bridge, I have to extract lines, polygons, etc. and I have to use a lot of algorithms just to get a good answer and a good orthophoto. I do not pretend that there is a unique solution, but I just wanted to show that with such a micro language and with a number of software libraries, you can do a lot of things.

Colomer:
There is a function in the Intergraph ImageStation that I think is not fully exploited yet; it is the "cursor on surface" button which instantly positions you for the height. We tested it and obviously, there are considerable problems. Imagine an operator wanting to retrieve or collect a road; the cursor sometimes shifts a little bit in X-Y and then you probably get a good Z, but not a good X-Y, which causes strange artefacts. But this is not the real question, the question is similar to the demand of Mr. Loodts that we should have access to many system functionalities.

Loodts:
If we use the original image correlation with the cursor, sometimes, for many strange reasons, it fails! You somehow fall into the gap for reasons I do not know. Even on flat terrain, with a lot of texture, you still fail! Oh, maybe sometimes you fall from the sky! (humor)

Adam-Guillaume:
In my company, we made the same sort of tests like Mr. Loodts; we carried them out for the same reasons, because DTM did not work. We performed a similar test using the Sobel filter which is quite equivalent, although Mr. Loodts' idea is better. We re-injected and replaced the images by the Sobel images, but then we had huge ridges without any meaning and the usual DTM softwares do not like that at all because they do not work adaptively. They should not create a triangle where there is nothing, but they should create lines everywhere where there is a fetcher on the edges.

Loodts:
We need a lot of functionalities for image processing. There are some configurations where you need such algorithms. The manufacturers can build a system if they want, they can also give a lot of functionalities, but we are asking for our freedom to build our own algorithms with a lot of tools.

Adam-Guillaume:
I would like to add that in order to build our algorithms, we need to know exactly where the images are and where half of the pixel is. It is very difficult to determine the origin of the DTMs and of the images for every manufacturer. If you make half a pixel error, you create an artefact in the ortho image. The manufacturers need to invent or add something to the software just to wipe out this line. But it is probably due to the fact that there is half a pixel error between one of the steps in the process, and you do not know which one because you do not know exactly what is inside the black box. What is the exact origin? Where is the center? Is it in the center of a pixel or what?

Madani:
I have a general comment. Mr. Colomer talks about the "cursor on surface" functionality. The "cursor on surface" are not designed for automatic linear extraction. The idea behind was to create a semi-automated DTM so we did not care to fix the XY coordinates. The "cursor on surface" derive the XY corresponding to a good point for correlation and is not intended for feature extraction.

Colomer:
Imagine that for a long time you have not realized or uncovered that the system gives you a new tool. Suddenly, you discover "cursor on surface" and you have the idea to use this tool for plotting. I know that "cursor on surface" is not intended for line extraction, but the idea is that the user always ends using the system in an unforeseen way.

Loodts:
Yesterday, when I saw a demo on automatic aerial triangulation, there was a lot of correlation and for the most part it was very good. You get a message when there is no correlation at all, so why not use this feature somewhere else? Let us just use this tool to build, extract or follow line features. By authorization, but of course, you need raster and vector together.

Madani:
Again, we are not arguing here who is right and wrong. Just to respond to Mr. Colomer when he spoke about opening the library for the user—to customize the software is another issue. The example you brought forward is truly misleading. "Cursor on surface" was developed for another application and it should not be used for something for what it was not designed!

Roth:
Let us go one step back since we already had a short discussion about modular features or structures that you want to have. All production typically faces a need to have an integrated system and to do everything first in a regular form. As the vendors of the systems, we see that the first step is to develop a software to integrate all the necessary steps to do all necessary operations. And now the second part of what you are saying is the integrated form of the system, you will need a very open way to do what you require. What you would like to have is the least square matching or aerial based matching and so on. Then you want the system to ask you for one image and for the other image. If there is no orientation, you want the system to tell you where the orientation is, then to read the orientation and so on. Or if you request the system to check your data, you take the image, and the system will give you the orientation, then the vector data; thus, the system will put it together. It does not matter whether it is a Microstation or not, for as long as the system will enable you to do and check your work. I think this modular structure is the main point; you now criticize the systems which are really intended to integrate everything in one structure and in one line. You just want the other way around first. It is very interesting to hear the demands in the market for vendors to also go all the way around and to open the system as far as giving you the possibilites to use the libraries, and utilize it for every purpose you want to do. Did I understand you correctly?

Loodts:
I just want to say that at the moment, the software that we are using is not structured as outlined; we cannot use the software libraries. You are telling me that this will be possible in the future, but I just want to test that. Also the question of opening the system, I believe that there are a lot of problems. We cannot do programming completely; there are always some new features that we would need.

Logistics and Integration of the System: State-of-the-Art of System Components

R. Héno - IGN France (Saint-Mandé, France)
J. Loodts - Eurosense (Wemmel, Belgium)
J.L. Colomer - ICC (Barcelona, Spain)

Summary

This is a paper from the logistics and integration group for the Lausanne OEEPE Workshop on "Application of Digital Photogrammetric Workstations". Topics that the authors have perceived as critical for production are listed in form of tables. Of course, the reader will find the list biased by the particular flavors of our systems: some features are over-emphasized and others not truly appreciated or fully understood. A feature perceived as very important in one system may be of marginal value in another.

Introduction

The ultimate goal of logistics is to achieve high productivity at a reasonable cost. A digital photogrammetric environment requires not only a proper configured system, but also good planning, efficient workflows and clever resource allocation strategies. Practical solutions are, however, site and project dependent. The particular features of the systems, the number of workstation installed, and site-specific policies and methods lead to no universal strategies and solutions for everybody. Again, we have tried to define major sources of problems.

Data management

Data management is cited often as the major inconvenience of digital photogrammetry. Pixel size and color have a direct impact on the hardware requirements, the data management burden, the visualization ergonomics and the overall throughput of interactive and batch application software.

Some processing tasks can last for more than a coffee break. In such cases, batch queues are used. Nevertheless, batch requires some type of resource planning. The ultimate goal of data and job management is that neither an operator nor a batch process waits for data or gets the job canceled because of lack of space. Avoiding as many pre-processing steps as possible certainly helps in maintaining a smooth workflow. In this context, data reformatting because of different standards is a waste of resources and a real frustration. In addition, data management must provide tools for properly identifying and archiving data sets (ie. data shall never get lost in hundreds or thousands of media volumes).

On the other side, interactive tasks and applications do require a short response time. There are also real-time functions that must have a response time of below one second. With small pixel size and color, systems shall not only be powerful enough for supporting CPU and IO hungry algorithms, but also be tunned for performance. State of the art and properly configured computer systems are key factors for smoothing much of the burden of data management.

Displays and user interface

Visualization ergonomics is fundamental in stereoplotting. Present systems do not match the roaming performance of optical systems, although some implementations do offer almost continuous smooth roaming at low displacement rates with no idle time waiting for new tiles of the image. High displacement rates that happen when browsing around and frequent zoom in/out lead to low productivity. Therefore, the system shall support as many views as needed and/or a second screen for simultaneous displays. High quality monitors are taken for granted.

Development capabilities

After some time, users start using the system in a way not foreseen by the vendors. The user may be willing to use its own software and procedures to enhance the base system. Therefore vendors shall provide an open, consistent and well-documented development interface. Open (documented) data formats and macro capabilities belong also to this open environment.

Conclusions

Digital photogrammetry is enjoying great success because the promise of:

- Easy to use end-to-end digital workflow that simplifies photogrammetric operations
- Full screen superimposition of images, graphics and menus
- Possibility of manual, semi and automatic measurements
- Film distortion frozen at scan time
- Leveraged on the growth of computer technology

By reviewing and discussing the enclosed documents we will probably get a quite realistic picture of the current achievements and needs of the digital photogrammetric systems.

1. Image Management

Feature	Benefits / Problems	Requirements	Comments
1.1 Image compression	**benefits :** - less disk space - less transfer time over the network - less search time on sequential devices (ie. Exabytes) - less job elapsed time (increased throughput) - less volumes to handle: init, mount, label, catalog/archive **problems:** - visual artifacts if overcompression - non standard computer system if hardware boards are used - impact on accuracy ? impact on correlation?	- must be a REAL standard: are results identical on evey platform? (imagine a color TIFF file with a JPEG compressed image scanned on a PS1 and used with PhotoShop!?)	- 8x compression on 15 µm images with small loss in accuracy (Robinson et al. Photogrammetric Week 1995) - it seems better to scan with small pixel size and use compression rather than use a coarser pixel size (the same reference as above) - 4x used at the ICC with no problems in visualization - are there reliable criteria (what compression rate for what pixel size, and what application) ?
1.2 File format standards	**benefits:** - makes data porting easy - spare file conversions in heterogeneous environments **problems:** - which standard? does it work really?	- user needs a REAL standard (a standard that works across all platforms)	- a simple TIFF B/W file scanned at the ICC gave problems at IGN France!? -even worse: the TIFF generated by the scanner was different from the one obtained using the file conversion utility!

Feature	Benefits / Problems	Requirements	Comments
1.3 Unattended scanning (automatic roll support)	**benefits:** - unattended operation (overnight processing) problems: - interactive radiometric tunning a posteriori (is it a problem?) - large free disk space	- free space for one roll : 500 images@15 μm = 35 GB JPEG compressed = 4x9GB disks) - shall be complemented by a smart scheduler for allocating volumes, automatic naming, create file paths, etc.	
1.4 Pre-processing at the scanner station	**benefits:** - uses the remaining throughput of the scanning station - 'clean' workflow **problems:** - pre-processing can interfere with the real-time requirements of the scanner, if done simultaneously with the scan	- the file formats must be compatible with all the digital photogrammetric software (see note on standards) - no time-out errors if processing jobs in parallel	- a scanner might have a throughput higher than the rest of photogrammetric tasks: the scanner station might deliver finished images ready for digital triangulation - ICC: 5 B/W photos/hour at 15 μm stored on tape (note: 0' for copy to Exabyte because it's done simultaneously with the next scan)
1.5 Storage	**benefits** and **problems** of tape, exabyte, DAT, CD ROM, optical disc, optical band…will be discussed during the presentation.	- high data transfer rate - high capacity - norms - robustness - moderate price…	- a hierarchy of storage: local storage, network storage and archiving storage can be useful to fix ideas. One could use magnetic disks for local storage, a juke-box of rewritable optical disks for the network storage and a juke-box of tapes for archiving

Feature	Benefits / Problems	Requirements	Comments
1.6 Enough free storage on the local disks: space to hold the data for a job step (ie. 2 strips for manual point transfer), or a chained sequence of job steps, or a batch queue	**benefits** - eliminates unplanned store-load operations to/from external storage because lack of space conditions **problems** - cost ? (50 cents/MB for the 9GB disks - is this a high cost?)	- neither an operator nor a batch job shall stall for data - automatic space allocation/data migration would be wonderful (look at what IGN France is doing!)	- Free space can be recovered either by using a process-delete strategy or by copying to the network server - Never use tapes for recovering free space: it takes too many manual operations to do it
1.7 Use of the network for transfering data	**benefits:** - flexible: no manipulation of external media **problems:** - unexpected dramatic slowdowns due to collisions (a common problem with high traffic on the Ethernet)	- low traffic (elapsed time) - fast interfaces at the workstation side	- Ethernet is not so slow: ICC achieves 0.5 MB/s with low traffic and fast WS (2 to 3 minutes/compressed image of 65 MB)
1.8 Remote File Systems (NFS) used by processing tasks	**benefits:** - spare of explicit transfer operations to the local disks - reduces local storage needs **problems:** - higher elapsed time: may be not critical for CPU-bound jobs, but critical for real-time visualization - potential for unexpected bottlenecks	- high throughput server (IO, CPU) - sustained speed of the network -network well supported	- IGN France works in remote mode for the image parameters (but not for the images themselves).
1.9 High speed network (ie. FDDI, ATM, Fast Ethernet)	**benefits:** - transfers faster (if the interface of the WS is also a high speed one) - enables remote visualization?? **problems:** - cost of the WS interfaces ? - standards?	- Standards, norms - WS interface shall match the speed of the network	- Solves completely the congestion problems?

Feature	Benefits / Problems	Requirements	Comments
1.10 Multiuser capabilities of the Operating System	**benefits:** - improves flexibility by allowing simultaneous file transfers, load/store operations to tape, background batch queues, etc. (some useful data management features included) **problems:** - real-time visualization affected by the extra load		- Advanced storage schedulers could be part of the Operating System - Performance tunning tools should also be there; throughput is achieved not only by raw speed but also by proper tunning
1.11 High speed CPU	**benefits:** - improves throughput (nights can be short!) - more runs of parameter-based software and/or more iterations of the algorithms - move tasks from batch to interactive (ie. on-line contouring) - 1 second interactive tasks ("real-time assistants") -heavy algorithms and/or small pixel size/color - CPU taking over large parts of the visualization tasks	- in "long" interactive tasks the user interface shall display visual information about the progress of the job	- Mandatory - Moving tasks from batch to interactive reduces planning/scheduling - What is the maximum time for a "long" interactive tasks? 5 minutes?
1.12 High speed disks and high internal bandwidth	**benefits**: - matches a high speed CPU - reduces elapsed times for IO bound batch processes -improves interactive speed and smooth roam		- Mandatory - RAID type of storage
1.13 Reliability, availability and serviceability (RAS) strategies of the vendors	**benefits:** - reduces down-times - improves problem tracking	- time-to-repair shall be short (8 hours maximum ?)	- Mandatory

2. Integration

2.1 Requirements concerning the softwares...

All the softwares should be customizable, and well documented. There should exist a developpement platform, with up to date documentation and examples. It should be possible to write script programs for batch processing.
Here is a sample of the basic requirements for the most commonly used tools on a DPW :

Feature	Requirements
2.1.1 inner orientation	- it can be done automatically. - it should be possible to import existing orientation (coming from other systems, like scanners...). - inner orientation uses and generates ASCII files.
2.1.2 exterior orientation	- it should be possible to import existing orientation (coming from other systems). - it should be possible to change the Z reference plane (to take into account the different perceptions of the operators). - exterior orientation uses and generates ASCII files.
2.1.3 epipolar resampling	- it should be possible to import epipolar sampling (coming from other systems).
2.1.4 correlation	- it should be possible to import existing DTM. - it should be possible to export DTM to other systems. - there exist powerful DTM edition tools.
2.1.5 image processing	- it should be possible to build its own tools. - it should be possible to process several images at the same time. - it should be possible to import and export the results of image processing.
2.1.6 data capture	- it should be possible to import data from other system via standard formats. - it should be possible to export data.

2.2 General requirements

Feature	Benefits / Problems	Requirements
2.2.1 Open software development platform (including IO routines)	**benefits:** - user/project specific functionalities can be developed (ie. snap to the projection of a 3D element, tools for quality control, etc.) - user can develop own image processing functions without caring of the file formats (or if the images are compressed)	- macro language, development language, subroutine libraries - well documented (examples included) and supported
2.2.2 Interface with existing built-in functions of the system software	**benefits:** - no need to re-invent/implement existing algorithms (ie. use the built-in function that computes the Z at a X,Y position) **problems:** - can be difficult to program if not well documented	- well documented and supported
2.2.3 Interface with an image processing platform	**benefits :** - justify the use of digital images	- well documented and supported
2.2.4 Interface with the real time visualization subsystem	**benefits:** - interactive behaviour tailored to customer needs (ie. "visit" all the points in a line-string, etc.) **problems:** - potential source of problems because of the real-time - can change with no notice with new software releases	- well documented, examples, clean and robust interface

Feature	Benefits / Problems	Requirements	Comments
2.2.5 Open file formats	**benefits:** - allows to integrate data processed on other environments (ie. import/export of orientation parameters, GCP, results from interest operators, etc.)	- formats shall be documented, including image formats - ASCII files for non-image data?	
2.2.6 Autonomous processing concept	**benefits:** - automatically senses the input data and sets parameters accordingly (ie. positive/negative, emulsion up/down) - automatically detects if a required pre-process has been already applied, and applies it if not - can take care of space allocation, and change the paths to the file automatically	- probably, a meaningful and rich file header for tracking the "history" of the data	
2.2.7 Chaining of job steps	**benefits:** - reduces key-ins (and errors) - reduces explicit launching of chained job steps (ie. automatic IO followed always by a pyramid generation)		- the autonomous processing concept is useful for chained tasks that are performed always
2.2.8 Integrated application software	**benefits:** - avoids having to abandon the session (ie. run contouring during an interactive DTM collection session) - spares writing disk files for the next application	- possibility to run software on a subset of data (defined by a fence or window), or process the whole data set - compatibility of the file formats	- processing time can be high if the whole data set is processed
2.2.9 Support Database and project/job management tools (ie. photo footprints, graphic indexes, etc.)	**benefits:** - organize/distribute models and related data (ie. models and orientations/GCP spread among several WS) - central repository of measures and parameters - easy management (ie. back-up) of critical data - some tasks could be launched from the DB via graphic indexes **problems:** - may introduce inflexibilities in the workflow - an additional subsystem to buy/manage/maintain	- shall talk well to the photogrammetric software - shall be easy to develop/implement/customize	

3. **Display**

Feature	Benefits / Problems	Requirements	Comments
3.1 Real time interpolated zoom	**benefits:** - larger zoom factors **problems:** - slows-down roaming, specially with color		- ICC: uses cubic convolution for orientations and bilinear for feature collection if zoom > 2.5 - IGN France: not necessary; with pyramids it's enough.
3.2 3D vector stereo-superimposition	**benefits:** - full control: on-line quality control, map updating **problems:** - visual artifacts (ie. large scale in dense urban areas) - proper selection of colors for vectors (working with color)	- must not slow down roaming - at least 16 colors ?	-ICC: because of confusions, operators have asked for a 2D secondary view -Selecting the colors of the vectors is really not so easy if color images are used (max: 12 distinguishable)
3.3 Smooth image and vector roam over the model	**benefits:** - confortable visualization environment **problems:** - roaming performance of optical systems not really matched: * wait for image tiles when roaming fast (browsing around) *problems with long vectors *jittering *delays if color or too many vectors or interpolated zoom -interruptions when changing zoom factor or enabling/disabling information levels	- must match the roaming performance of the analytical plotters - can be set off from a given scale on	-Jittering problems do not appear in the systems the ICC is working with. Other systems may have similar or additional problems in visualization.
3.4 Cursor	**benefits:** - user customizable (color/shape/size) -adjustable sensitivity **problems:** - cursor jumps	- no jump at all	

4. HARDWARE

Feature	Benefits / Problems	Requirements	Comments
4.1 Secondary stereo view(s)	**benefits:** - avoid 'where am I' type of zoom outs during data capture - reduces 'browsing around' **problems:** - slows down display smoothness because of the roam in the secondary views - needs a second screen if the primary one is not big enough	- cursor tracking on the secondary view (the stereo cursor is also shown on the secondary view) - image and vector roam on the secondary view	- IGN France: neither stereo nor roaming is really needed - ICC: this feature is not used; operators use a small 2D window with vectors (see next)
4.2 Secondary views for 2D vectors	**benefits:** - look at the results in 2D (to check for correct linework, specially when plotting in dense urban areas at large scale) - avoid 'where am I' zoom outs and browsing around - allows to display many menus **problems:** - slows down the display smoothness because of the vector roam in the secondary view - needs a second screen if the primary one is not big enough	- cursor tracking and vector roam on the 2D view	- ICC: used always; it has been mandatory for a urban mapping project because of the confusion problem due to the 3D superimposition
4.3 Large screen	**benefits:** - simultaneous display of different views (ie. point transfer with > 2 images, secondary 2D and 3D views, etc.) - larger field of vision (ie. for contouring) **problems:** - difficult to adjust the color guns (reduces display sharpness) - non standard equipment (very Intergraph specific) - cost		- even a large screen might be not sufficient; a second is a more general solution (see below) - the largest standard monitors are smaller than the Intergraph one

Feature	Benefits / Problems	Requirements	Comments
4.4 Dual screen	**benefits:** - similar as with large screen - screens can be standard - possibility to see the vectors with more complex symbols - possibility to display many menus **problems:** - cost?		
4.5 Screen dot size	**benefits:** - sharper images	- dot size < 0.30 mm	- there are very high quality monitors with dot = 0.25 mm
4.6 True color systems	**benefits:** - improves feature identification **problems:** - high data volumes leading to overall low performance	- use of simultaneous RGB JPEG compression	- pixel size can be coarser because of the lower resolution of the color films
4.7 Image enhancement tools	**benefits:** - improves visualization	- gamma, linear, etc. - must be fast and customizable	- used
4.8 Trackball	**benefits:** - cheap **problems:** - accuracy ?		
4.9 Handwheels	**benefits:** - familiar to operators trained on analytical plotters **problems:** - additional cost ? - getting familiar if brand new operators		

Feature	Benefits / Problems	Requirements	Comments
4.10 Polarized screen technolgy	**benefits:** - comfortable for the operator: simple glasses that can be easely attached to the normal ones **problems:** - monitor is more expensive and rather fragile - ghosting ?		
4.11 Shutter technology	**benefits:** - ghost free stereo display **problems:** - fragility and cost of the eyepieces - weight of the eyepieces		
4.12 Screen stereoscope	**benefits:** - cheap - may be sufficient for mere controls **problems**: - not comfortable - the field of vision is narrow		- IGN : has a screen stereoscope on the image server to control the exterior orientations. - might be sufficient for educative purposes.
4.13 Anaglyphs	**benefits:** - cheap - may be sufficient for mere controls **problems**: - not accurate - not comfortable		- might be sufficient for educative purposes.
4.14 Voice recognition system	**benefits:** - spares 'clicks' on the menus: allows the operator to focus on the image. - more freedom and speed, specially with handwheels **problems:** - stereo glasses and a voice system might be too much for the operators? - the recognition system needs to get trained with the voice of each operator; afterwards, the questions is if it is robust enough (minor changes in voice tone)		- might be not so important with trackballs or hand-held cursors: since they provide also the 'mouse' functionality - are some experiments being done ?

General Discussion on Logistics and Integration of the System:
Statements and Comments by the Manufacturers on the Questionnaires

In the following open discussions, many questions relating to various topics were raised by the working groups and hereby answered by the appropriate parties. The transcription should be considered only as "minutes of the meeting; therefore, the reader is advised that the answers provided herein by the Manufacturers should not be interpreted in any way. These statements or comments are not definitive, therefore, not conclusive. The Manufacturers reserve the right to re-define, clarify, change or modify the statements or comments given before the assembly.

TOPIC: Image Compression and File Format

Héno:
I would like to refer now to the tables and open the discussion on the questions for the manufacturers. The first point in the agenda is image compression and we have already said many things about it. We can compress without a loss of accuracy with a ratio of up to 5. The benefits and problems are quite obvious and they are listed in the table. What we want to emphasize, however, is the requirement. We would like to know if it is possible to have a standard as far as compression is concerned. We need something that we can use from one station to another in order to allow for an easy exchange of images.

Tempelmann:
I would like to say a few words about image compression and the ratio of 1:5. Try not to use 1:5 for all your images because the effect of JPEG compression depends very strongly on the data which contains the images. If you have large, homogenous structures in it, JPEG will achieve a very good compression ratio. If you have a considerable number of fine structures, you will get very little compression. We have already tested the shifts which arise from JPEG. Already at a compression ratio of 3:1 if you use it on remote sensing data with fine structures in it, for example, you can already get geometric shifts up to 1 pixel.

For aerial images, it is normally a bit better in this situation, but it also depends on the noise which is contained in the images. If you have much noise in the images, JPEG will not compress well. If you have low noise, you may compress in the region of up to 1:3, 1:4, or even 1:5 with possible geometric shifts of 0.1 to 0.2 pixels, but you have to accept these minor shifts. As Mr. Ackermann said, if you are computing a DTM with many points, it is not so bad because these shifts are random, with JPEG at least inside the 8 x 8 transformation matrix. So do not say, I want to compress 1:5. It is better to define a special JPEG compression factor. A Q-factor of 75 is the standard quality for visualization purposes. A Q-factor of 75 is already too much for our purpose in geometry as JPEG has not been designed for geometry. So what we recommend is not to use too high factor. The Q-factor of 90 will give you a compression of about 10:1, appropriate for industrial applications where you have large homogeneous surfaces. For aerial photographs, a ratio of 3:1 and for remote sensing data, a ratio of 2:1 might be appropriate.

Madani:
Now everybody agrees that in digital photogrammetry, we are dealing with a huge amount of data and the only way we can handle that is by image compression. Now the questions are: what kind of compression ratio do we have to use? in what application? and what kind of algorithm do we have to use to achieve that? Based on this JPEG board, which stands for "Joint Photographic Experts Group," its algorithm is very well known in the electronic and image processing communities. We implemented JPEG in our environment and we are now using it. Based mainly on our users' experiences, we found out that the existing film with 30 line pairs per mm allows a compression factor of 1:3 to 1:4; then you do not see any noticeable shifts or degradation of the image. There are some published papers from the "Academia" not only from the users, but also from Mr. Robinson in Australia and Dr. Ackermann of Inpho; we have done our own study as well. Nevertheless, we have not had problems whatsoever with this ratio. The question now is, do we want to use it or not? It's either we deal with many or few hard disks, as Mr. Colomer said. Not only you compress the image to save storage space, but also the transfer of data is speeded up. There is another better point, algorithms which were proven to be 100% loss less, simply do not exist. But if you limit yourself between 1:3 or 1:4 times, in case of correlation up to 10 times, we have not seen any problems in any applications, such as triangulation, orthophoto generation, or stereo feature extraction.

Becker:
I have a question regarding the actual hardware. Intergraph has a hardware board on their ImageStations which I do not know how long it will be available? But what is the future on other hardware platforms? Are we going to continue seeing image compression boards?

Carswell:
The future is that we will have software JPEG on-the-fly; therefore, we will not need our JPEG board anymore. I am hearing a Q-factor of 90; we never use a Q-factor of more than 25 on our images and that gives about 3 to 4 times compression. As for color images, we use a Q-factor of 15 and that gives about 3 to 4 times compression as well.

Heipke:
I would like to add some theoretical considerations as to how JPEG works. There is obviously no way that you can predefine a compression ratio which you desire. If you say you can deal with 5 times compression that only means that if you run your compression, and you see that it is 5 times compressed you are satisfied. But there is no way you can introduce this number 5 into

the algorithm. What you can introduce, and that is the only thing you can introduce is the Q-factor which is a measure for the compression. The Q-factor is defined in different ways and that is where we should have a real standard. When you say 90 and Intergraph says 20, I very much doubt that it is the same value we are talking about. There is probably a factor of 4 in between or something like that.

Héno:
I have a question concerning standardization, is it possible to compress on one different brand work station, and then decompress on another different brand work station?

Carswell:
I think that we already have a standard, JPEG is the only one being used right now in the industry for real time image compression. I think that if we want to have a JPEG file that everybody can use then I think it is up to the other vendors to use our standard. Otherwise, we will have to re-design our JPEG boards and everything else that is associated with it. But if it comes to that, maybe we will. In any event, as I said, we are going to be moving to the software JPEG in the future anyway.

Dam:
We are focusing on the TIFF 70 specifications for JPEG standard because we believe that it is not only a very common standard, but an efficient processing standard as well because it will allow tiled JPEG. Currently, the raster format is not very efficient for most image processing work stations. So we hope to settle and we hope that other vendors will join the rest of the industy to settle on TIFF 70 JPEG.

Héno:
When you use many different files, you immediately realize that you need a real standard to use your files in any of your work stations. We had problems at IGN on the Helava station reading TIFF files coming from the PS1.

Carswell:
Helava probably does not recognize the tiled typ, is that why? We also have translation functions on the ImageStation to translate it into a TIFF untiled and with no overviews.

Kölbl:
We did not have any problems transferring from the ImageStation to Helava, and the other way around, but it was TIFF untiled that we used.

Roth:
If we are talking about TIFF and the standard TIFF, I think the most important question is, what is a standard TIFF? How do we distinguish if we are talking about the tiled TIFF or the regular one? Additionally, it is also important that we inform our users better about the standards we use in the software and also show them all the possibilities within. For example,

how to transfer the data between the different systems. Very often when you send a TIFF file, you might encounter problems with the tiled format or problems with the color in the local coordinate systems which is also defined inside the TIFF header. Therefore, I think it is essential to obtain a standardization of the different systems so that everybody can read and write the TIFF files. Furthermore, we will have the opportunity to exchange TIFF files all over the network for I also believe that in the future, TIFF files will be the main universal format to exchange data and we will not have to go back to the raw format.

Madani:
It is a fact that users want to deal with multi-system environment without any hassles or difficulties; that is to take the data from one system to another. At this point, I think this is a "wish" because there is no such thing available in the market today. What the vendors can do is to try to accomodate the users as much as they can. Right now, for example, we are dealing with raw imagery, TIFF format, tiled TIFF, Intergraph Raster format, JPEG board, non-JPEG board and so on. This is all we can do at this point–we are dealing with a variety of different raster formats. If the digital photogrammetry community or somebody official from within mandates that there should only be one raster format then everybody would follow. It will be much easier for any vendors or developers to come up with one definitive format and then get out of it, otherwise, at this point, what else can we do? Clearly, we have to satisfy all our customers, and give it our best to provide all the possibilities you want. But please, do not say that your scanner is acting funny or your other scanner is doing the job completely different from the other one because they are two different brands!

Dam:
We also try to increasingly support additional formats as we find new customers. We need those formats and so it is sort of on a case by case basis that we add new formats. We are publishing a list of our current specified formats and we hope that will help. At least new users can see what we can read and write. We have not added TIFF tiled yet, but we are in the process of adding it to Socet Set so we can be more compatible with other work stations. There are hundreds of formats out there and they are not always easy to add, even one single format like TIFF; it is such a huge, complex format. Moreover, we are even adding supplementary capabilities, for example, gray scale specification and look up table specification. All these things are going to be nailed down eventually, but I must admit, it is a slow process.

Dupéret:
I have another question on file formats and images. Are the manufacturers ready to manage 12 bit or 16 bit image matrices?

Madani:
I do not want to say what we are planning to do at this point because it is not officially announced yet, but in the next generation of our soft copy

photogrammetry, we are going to handle 13 to 16 bits imagery and on-fly re-sampling, as well as on-fly convolution correlation.

Dam:
Because of our history working with the U.S. Government, we have always worked in a higher than 8 bit environment. We do not propagate to commercial systems because they do not use the commercial systems standards. We can operate on our scanner, presently in 2 byte TIFF formats as well as in Vitec formats, which is our native Socet Set format. There has always been the capability to do that, although we do not use it much and I am sure that will change in the future. Certainly though, you get a little bit of a slow down, that is one of the drawbacks and the storage requirements go up so you have to consider whether the benefit is worth it. If I take into consideration the compression, then there is the solution and the 2 byte may not be too difficult to handle, although the direction of going to higher byts for certain projects is important and necessary.

TOPIC: Scanning in Batch

Héno:
I would like to invite you and take a position on the next point concerning scanning. Our users are interested in scanning in batch and there is no scanner available to allow this for the time being. Do you have something to say about this topic?

Roth:
Of course, I have to say that there is something available because we put in the new generation of scanner, a device of roll film scanning and the idea is to really do it in batch overnight. We have to be honest and say where the problems arise when you run such a process in batch. You need a lot of disk capacity and you have to pre-define a number of parameters like the position of images on the roll you want to scan. Furthermore, I think it is not just the hardware, but also a software power package that you would need to handle batch scanning expediently. I agree that the scanning process should be done in an automatic way overnight because you can obviously save time and money. The operators who do our scanning, they take the photographs, they put it in and set up the parameters, leave for a few minutes and then come back to do the next scan. I think in the future, this is a process that can be handled automatically.

Eidenbenz:
Let's take the example from IGN France, they have 50 images per unit, as I understand and in total 1,000 units. If you take 150 meter roll film, you can easily expose this in a day. This gives you say, three different units you have to fly and they might not have been flown under the same condition. So how do you adapt this at night automatically?

Roth:
I think the answer can be to just do it by software. That means in the first step to pre-scan all the images or only one image per strip, to make sure you get the radiometric information and to adjust the settings. It means you set up the parameters once as a pre-work, save these parameters and finally, scan the roll overnight. One drawback in doing it this way is that every strip will be done with the same radiometric information or parameters. It should also be possible to prepare these parameters automatically. However, an important question is, if the system changes the parameters automatically, then what about DTM correlation, for example? Will the correlation process be affected? We are now in the phase of testing that.

Kölbl:
From a University's point of view, maybe we do not have all roll films, but I still do not see the future for automatic scanning of several images. What would be ideal is to have a system like a photocopy machine where you can just put the pile of papers into the machine that you want to copy; you set up the parameters, then you have the machine working day or night, come back and your copies are made. I just do not see any developments on automatic scanning in this sense.

Madani:
I have another comment. Everybody here agrees that it is much better to scan diapositives than negatives because we found out in some of the applications even in dodging, that diapositive takes care of the enhancement of the imagery. Now if you are using the negatives, which of course, is better from the operational point of view, you may run into a problem of how to do the automatic auto-dodging of the film in order to give a better appeal to the image for the correlation technique. This is something that needs to be worked out as well.

Becker:
Just because you make diapositives does not mean you cannot connect them to a roll. Essentially, you just stick them together and you get a roll of diapositives.

Colomer:
Regarding the idea of pre-processing at the scanner, the idea is to have a clean work flow and to run, for example, orientation and pyramid generation and whatever else at the scanning side in order to deliver something that is finished. I think everybody can agree on this; the only problem is that sometimes when you run an automatic process in batch, in the scanning work station, then you might be confronted with "time-out." I mean the station must be powerful enough to handle all potential problems.

Carswell:
You are right about the scanner taking up the process as a whole; of course, it has to do with all the data transferring from the scanner into the disks and timing is critical between the swapping of the CCD array. But you can scan

locally to your disks on the PhotoScan, for instance, and mount those disks on the network and do orientations. I have done that on my machine. I have got a paper here, if anybody is interested on how I did that. So I was doing my interior, relative and absolute orientations on the ImageStation over the network on the disk of the PS1 and I was even doing stereo re-sampling. And then the stereo re-sampled images were used on the ImageStation, but the images physically remained on the scanner the whole time and that worked without any time-out errors, shift errors or anything like that.

TOPIC: Storage and Back-Up of Raster and Vector Data

Héno:
Storage of data and especially of image data is of great importance in digital photogrammetry. It is not very interesting as far as photogrammetry is concerned, but storage is something to care about when users require a robust and high capacity back-up support device. A back-up support has to be a standard device, otherwise, you risk not being able to read the data after changing the hardware.

Roth:
What I have seen available in the market which is already on the UNIX machines are hardware and software for archiving. What you want to do is store the data in some kind of "juke box" which should have an intelligent software knowing exactly which data to transfer to various medias and allowing retrieval whenever necessary. There are products already available, like from Hewlett-Packard and so on. Another topic should be the operating systems; I think that UNIX has a lot of advantages. You can use a NFS, an extended file system and that will give you the possibility to add a lot of Gigabytes altogether into one logical disk and you do not have to look or check by your server or data where they are coming from. It is of course necessary that your file transfer system is really working well and I am talking about TCP/IP or another network systems. If somebody has network problems then you should not use these facilities. Nevertheless, the hardware and software are already available on the market.

Madani:
It is true that the ideal case is to do your interior orientation while scanning. Not because we did not know it, but the reason why we did not have it on the Photoscan PS1 is because the purpose of the Photoscan PS1 is to do the photo alignment on the instrument and to be able to scan only the necessary part of the image you want to. Therefore, we had to use a rigid body transfer machine to align the camera to the film and to scan the photographs almost in the photo coordinate system. But everybody knows that when you are doing interior orientation, if you want to reduce lens distortion, you need to apply higher order transformations. We did photo alignment with a rigid body transfer machine to make sure we align the photograph in a corridor or

any particular part of the film. It was much easier for us to use the raster coordinates and plug them into the fly and not have to do any interior orientation. This was the reason why it was not done in the past.

Dam:
I would be interested to hear from all the users the different storage situations that they are using currently. I have come across a variety of different facilities. There seems to be a break between long and short term storage between wanting to archive today's or this week's jobs versus something you are going to stay safer for years. You do not often save everything you scan or work with forever. Maybe there is a need for higher speed, short-term storage and lower speed, long-term storage. The DLT tapes are now coming out on platforms and offer a very fast, short-term storage of about 1 to 2 megabytes per second to tape. Another alternative is the CD-Rom technology which is going to be increasing by a factor of 10 in the next year with new specification from Sony-Philips. Those seem to be the best long-term storage. We are using what the rest of the data storage technology community is using. You can choose what is best for you because each operation is a little different. We are just trying to stay flexible.

Héno:
What you just said actually answered the questions we have concerning storage, unless someone has something specific to say about the topic, we can just move on to the next topic of discussion.

Tempelmann:
I have a few last comments about NFS storage. People often complain that their network is so slow and that is mostly due to the use of NFS. NFS is very efficient for reading and you get rather good transfer rate. However, NFS is slow, it has always been slow, because NFS is designed for safety; each transfer which is done from a client/server is acknowledged first before the next transfer can be done. There are some devices which could make it a little bit faster, cache devices which allow an immediate response, but NFS writing is always slow. Therefore, if you have frequent access to files via NFS, for reading you might be satisfied, but you should not write using NFS.

Héno:
Could NFS be suitable for simple visualization of the images?

Carswell:
I was doing orientations and I had a PS1 mounted over NFS to my ImageStation. The images were still on the PS1 when I was doing orientations on the ImageStation using the images on the PS1. All I was doing was reading and there was no problem. I could not tell according to the access time where my images were. There was no difference in speed as far as I could tell.

Madani:
May I also add another comment here. We found out that for stereo roaming, it is better to have the images locally than through NFS. If you want to have a smooth roam, you should do it that way. But for triangulation or batch processing, you do not need to have it on your system.

Roth:
I can just confirm also that we did not try to use the fixed images and the moving cursor, you can also work in stereo plotting over NFS, and I think it is the same as what Intergraph is saying here. All the processes can be very fast on NFS. If you are just doing real roaming, you should have the images on the local disk because it is better for your eyes.

TOPIC: High Speed CPU and Multi-Processor Technology

Héno:
There is still the question of managing the images. Is it really necessary to have a high speed network, high speed CPU, high speed bandwith, high speed disk? It is a question of budget, of course, and a question of what exists in the organization, what kind of jobs you have to process and how fast does it have to be done. Any comments about this issue?

Colomer:
My comment about high speed CPU is that you will always exhaust the CPU power and the question is about multi-processing capabilities. We will need dual or quadruple processors. Is the next generation software really going to make use of this? For example, by devoting one processor to the visualization of the compiled data. Are there any advances in this field?

Carswell:
When we get our NT conversion running, which should be in about a year from now or so, it is going to run on multi-processor Penthiums. One advantage of NT in general is that it is written to take advantage of multi-processors even if the software is not. NT will use the multi-processors on its own so you will not have to write a special code to send one process to one processor and another process to another processor. While I have the microphone, I may as well talk about the very last item under the "Image Management Section," #1.13 concerning the "reliability, availability and serviceability." In the comments on the paper I have in front of me, it says that, "analytical systems have near 0% downtime and ICC still has a 2.5% downtime with digital." I just want to say that this means you have 97.5% uptime. In addition, digital photogrammetry has only been out in the market for four years and we are down to 2.5% downtime, and analytical plotters after four years, I am sure they were not that efficient.

Tempelmann:
With regards to the speed of the machines and the need for multi-processing, the new Sun-Ultra System will soon be available for our systems. Currently, Ethernet is changing from 10 base T with a capacity of 10 Megabits per second to 800 base T with a capacity of 100 Megabits per second. The graphic speed will also increase tremendously. Of course, the CPU is getting faster as well. If you think about multi-processing at the moment, the next generation of processors will be twice as fast as the previous ones. Is multi-processing really worth thinking about? I support the use of multi-processor for various applications you are running at the same time so there is not much effort to install additional processors. But if you look at the other side, is it really worth the effort to change the software to a multi-processor solution which will use different processors and separate processors running at the same time? It is not a problem even if you use one CPU, but the development of the hardware will be the biggest issue. So is it worth the effort?

Carswell:
According to the Computer Journals that I have been reading, everybody is moving to multi-processors. I think that is going to be the future. I do not have the machine yet, but I am told that it is going to have four 200 megahertz processors in it; it is almost like buying a sports car with a large engine inside. I think that is the future: multi-processors. Super computers now are also multi-processor machines.

Madani:
I have another comment that photogrammetry is not an optical nor a mechanical device anymore, it is another application of the computer. Whatever the computer technology provides, photogrammetry has the leverage on that kind of application. So it is available and we will take full advantage of it.

Roth:
I want to comment on what you just said; there is another issue and it is not an issue of just the hardware anymore, but also the price that you want to pay for a computer or a machine. There are a lot of UNIX machines out there that are much faster than we are talking about. It is a fact that you just have to pay more and so the question is, is it really necessary to spend the money on the mega or super computers or should we opt for low-cost processors? where will you gain the money?

Carswell:
I suppose we will just have to wait and see what the users want, but as far as I am concerned as a user, if it is any slower and not instantaneous then it is too slow.

Colomer:
I have a very brief comment on downtime. It seems to me that this 0% downtime on analytical plotters is unrealistic and therefore, an overstatement. Do vendors have figures on downtime on analytical plotters?

Eidenbenz:
Electrical problems on one side can easily take you 2 days until they are fixed. On the other side, you have the computer that runs under UNIX, which is actually a PC and you have a separate back-up unit. If and when the computer goes down, you can exchange it immediately by another computer, which takes maybe 1 hour and then it is up and running again. But you should make a trade off between the downtime of the people versus the downtime of the machine. I think that on the collaborator's side, we have much more downtime than on the machine side, on the hardware and software combined together. We can influence or control the machines, but not so much the people side eventhough it is more important.

Piedfort:
We have three analytical plotters. Last year, I lost about one complete job because the software was unavailable for one of our plotters and I had to change the whole software and the computer. The second comment I have is that I had hardware problems regarding the CPU of the plotter. Overall, with all of our production, I think our downtime was about 20 to 25% last year. First, it was the software, we collected sphaghettis and then when we put it in the database; I saw that only about 85% of the collected data was transferred, and I lost 15% of the job in that one process. So finally, we changed the whole software. Nevertheless, problems continued to come up. For example, sporadically, we had all vectors presented twice. So I can tell you when I see on this paper that there is 0% downtime on analytical plotter that it is not valid.

Madani:
We do not work in a perfect world. When we look at the statistics, we are using a sample to predict the population. In any event, when you are dealing with a very complex system, you should expect some downtime. You cannot say that every aspect of life is perfect. I do not know how you arrived at up to 2% downtime and beat on us because the system is down. If you take a closer look at life and everything else around us, there are problems everywhere.

Dekeyne:
I have comments on the downtime on the AP environment. We have a good experience with the 24 AP stations at the IGN. The other bigger problem is that we often hesitate to go to the next release because vendors will always say that the next release is ready and it is much better than the older release. But a change is generally a very big problem for us; downtime escalates tremendously. If we plan to change the release next year, we must plan ahead and account for maybe 10%-30% downtime. As for the releases in the GIS software, we are always 1 or 2 versions behind. This is the problem with this kind of environment, especially on what we do, we have an integrated solution with different vendors working together and sometimes the different releases of softwares of the different systems are not really compatible. This is a problem both in analytical or digital.

Eidenbenz:
It is actually an insurance problem. How much are you prepared to pay for systems that run 365 days a year and 24 hours a day? You can have multiple systems and you still have the risk of a certain downtime. You can have a second crew waiting until the operator goes down, but your prices are going up and you cannot afford this anymore.

Colomer:
First of all, I would like to apologize, we should never write analytical plotters having 0% downtime anymore. I have just asked the head of the operators to give me the figures of the analytical plotters, but he just gave me a feeling, not a figure. I tried to track down the introduction of the new technology because it was new and the computers are better, but you are more critical with the new technology. Secondly, I would like to refer to a study about different industries' downtime cost, of industries such as brokerage, credit cards, pay per view, home shopping, catalog sales, airline reservations, teleticket sales, packaging & shipping, etc. As an example, they reported a $6.45M per hour lost!

Eidenbenz:
In our profession, it is not so critical. Downtime can be critical in the private business sector, but in the public sector, it is not the same problem.

TOPIC: Transfer of parameters of Inner and Exterior Orientations

Héno:
I suggest we start again with softwares and I think that the users have some experiences to share. In the tables of introduction are some general requirements, which must exist and must be delivered with the softwares like documentation, for example. The users want the software to be customizable most of the time. But more precisely, we would like to talk about inner orientation. We have already said many things about it, especially Mr. Loodts. Its seems that having an automatic inner orientation is something that is requested and it is not done yet in all photogrammetric systems; for instance, with the Socet Set software we use in the IGN, we cannot do the inner orientation fully automatically so we lose too much time. Furthermore, many users would like to see the results of inner orientation in readable files in order to use it afterwards. In addition, we would be interested to dispose on facilities for an easy transfer from one station to another. It should be possible to import existing orientation. The same is required when doing exterior orientations, but this process is different when using digital triangulation.

Madani:
Speaking of interior orientation, we know that it is the transformation from one coordinate system to another coordinate system. It will only work if the

coefficients of the transformation reflects the type of transformation and if the raster coordinate location of the fiducial is the same in both environment in which the transformation coefficients are used. For example, if I say fiducial #1, row #10,000 and column #6,000 and it is consistent from one scanned image to another one, of course, you can use the coefficients of the transformation. Otherwise, if you use two types of scanned imagery, it is meaningless, you cannot use these coefficients from one system to another one.

Loodts:
What I mean is that when you make an inner orientation on one system and you deliver to the client a transformation file, it is not changing. You should be able to transform the inner orientation from Intergraph to Helava directly without any problems and without any changes. Well, it is not very easy. I tried to do it and I lost a lot of time.

Madani:
To reiterate what I said, it is the matter of the coefficients of the transformation from one system to another. But this does not solve the problem because if you locate the position of one fiducial in another system and it does not match with those coefficients then you will get the wrong inner orientation.

Héno:
Maybe it is not the question of having the orientation parameters, but it would be sufficient to dispose on the coordinates in both referentials, then it would be sufficient to reinitialize the calculation. Actually, that is what we do with the Socet Set in our orientation module. We do not have the actual orientation parameters, but just the film coordinates and the image coordinates.

Madani:
The coefficients, the measurements in raster, the photo coordinates and the camera system parameters are all in ASCII file at the ImageStation which anybody can use.

Kölbl:
I have realized that you only have 3 files in the Intergraph system: the file photo, the file model, and the file control. It is wonderful for back up, but if ever you want to interfere within the photo file, you have to edit it, then you are lost.

Madani:
We are extremely flexible and you can even name it anything you want.

Roth:
I have one point regarding the orientation. If we say we want to export orientation parameters to different systems, we are doing that in both the digital and analytical ends to make sure that we can also support orientations or aerial triangulation that are done from one system to another.

We have come up with this kind of standard which we call "Forex" that every line gets a key word so that everybody can read it independently. We used this standard in the analytical line, and applied it to the digital line. I think it is a good idea to standardize the ASCII file so that everybody can have an easy format. Also with the PS1 header file, what we do is we take the measurements directly from the alignment to our camera file and do an interior orientation. I think the interior orientation is not a good example because this is done very quickly. Furthermore, when you are doing it automatically, it is not a question of time, it is the question of efficiency– doing it once and re-doing it when you know you have already done it somewhere in the process. I think the critical point is the exterior orientation because it needs more parameters.

Madani:
If you look at the translator option of the ImageStation, there are many ways of extracting exterior orientation, measurements, as well as orientation parameters in different formats. The translator option is where you want to extract the measurements and introduce them for other systems like the Albany System and this is also the place to indicate if you want to use it for other programs like Pat-B, Pat-M and others. We even have a generic format which allows to define your own format. But again, this goes back to standardization. You cannot satisfy everybody. Everybody has different procedures, like somebody would say, I want to have in column 1 the X coordinate in a radical way, the second column with a point coordinate and the third column with the Y coordinate. There is really no standard to follow. However, we are doing our best to have a user friendly package in the market.

Tempelmann:
Let me just add what Socet Set is now delivering. There are ASCII files with documention, and there are ASCII files without documentation as it is not assured that they will stay constant. The other way to access the files of the Socet Set system is to use the developer's tool kit. This kit will give you a set of functions, you can retrieve files even if the files were changed. Moreover, if such tool kits would exist for other systems, it would be quite simple to read and transfer files. You should not even have to care about the file formats.

Eidenbenz:
I think to some extent this is a fruitless discussion. I think we should force all the vendors of scanners and systems to sit together and bring forward a transfer standard to the ISPRS and then we decide on the resolution and only then we might have the standard we are asking for. I think we had the same discussions 50 years ago. 9 by 9 inch cameras were not born as a standard at that time; it was the manufacturers who did it first and then another had to come up with the same standard. I remember the cameras where the fiducial marks were in the corner, and those of the Zeiss cameras were in the middle and now we have 8 fiducial marks. So there is sort of an adaption also, but the only idea would be to either wait until there is only

one vendor that survives then we have a defacto standard or we bring forward a standard to the international society and decide upon it.

Taft:
It seems to me that this might be a good task for OEEPE—to get all the information together and to work out recommendations on which all the vendors can then agree, rather than expecting our salesman from Intergraph, Matra, etc. to sit around and argue for hours and say that they are the best.

Madani:
I do not want to prolong the discussions because as you said, users want many things and vendors are limited to satisfy some of the standards which users believe are in the market. Two years ago in the ISPRS meeting, I suggested to Dr. Dowman, who is the chairman of the Digital Photogrammetry System, to come up with some standards because in the computer world, we are nobody. Photogrammetry is a very small community. We cannot enforce the raster format. We are nobody compared to the rest of the world. Either it comes from all the vendors working together or from some dedicated professionals of ISPRS or ASPRS to come up with one standard procedure. It would be much easier for any vendors to follow one real standard that everyone from within the photogrammetry community has agreed upon.

Kölbl:
There was a suggestion that OEEPE should work out recommendations for standards in digital photogrammetry. Please understand that this workshop is part of the engagements of OEEPE and this workshop is organized by OEEPE. I will pass the suggestion and I would like to say that OEEPE is aware of the problems. We have already discussed these issues and we will continue to do so. It is, however, evident that we need a collaboration of the interested parties. My suggestion is to protocol the discussion and to bring forward the topic to the steering committee of OEEPE.

Vanommeslaeghe:
I just have a slight remark, I think that the problem is very complicated because it is not simply just an exchange of orientation matrices. But you also have to care for the application, for example, you have film deformation and additional parameters.

Madani:
I believe that you are right because even when you talk about photo coordinate system, it depends upon what kind of film deformation or mathematical distortion you apply, you get a different refined coordinate system. Any bundle adjustment out there in the market uses radial distortion. What we can do for those who have it is we have in the photo system two coordinate systems, a raw coordinate system and our own refined coordinate system that is based on our own mathematical model which we apply to the measurements. So for someone who does not have that kind of standard, or does not like our refined coordinate system, we provide them the photo coordinates which essentially refer to the camera axis. Because currently,

when you read the camera calibration reports, the new cameras have more information about the cameras than the only lens distortion. Besides using the average value of lens distortion, we can also apply it for each quadrant differently. If somebody does not want to use it in that way, then a refined coordinate system is provided. Again, the system is far more complex and needs more in-depth thinking. Therefore, if OEEPE or somebody else comes up with standards and say that this is what we need then we will stick to it.

Kölbl:
I would like to ask this question in this context. When I was a young assistant, I was with Prof. Schwidefsky in Korlsruhe. He was heavily engaged in the elaboration of the DIN-Norms which define a multitude of elements for photogrammetry. In this context, I would like to ask if the vendors apply DIN-Norms or are they just a German standard which is not recognized in the U.S.?

Madani:
I am not aware of that standard. Let me reiterate again that digital photogrammetry is changing so rapidly because of the computer technology. If somebody comes up with standards, it would be much easier for any vendors or developers to use and follow the same standards. Not only the users are spending so much time going through this kind of trouble, but vendors as well. As far as Intergraph is concerned, we will do whatever is necessary if you give us an official approval that this is what everybody needs.

Eidenbenz:
As I said earlier, this is a fruitless discussion. When I fly a block, I deliver the film and the calibration protocol, therefore, you should come up with the same idea on the digital side, it is as simple as that.

Roth:
If vendors collectively cannot agree upon or come up with a standard, then each vendor will just end up providing to the users their own version of the standard. In consequence, everytime we have a forum like this, vendors and users alike will have an argument. Like what you said on the cameras; perhaps if everybody can converge and deliver the best solution then it would make a significant difference, otherwise, only the strongest one will survive. I think that would be the worse situation that could happen. It will be better for all of us to sit down and have an cooperative discussion and finally decide on a standard for the orientation because it is as complex as it could be. But for the user it should be as easy as possible even if he just wants to press the button and say, "convert my Helava orientation or Intergraph orientation to this standard." By the way, I am just talking about photogrammetry and not raster formats because that is really different and we only have a very small part in the world of raster conversion.

TOPIC: Epipolar Re-Sampling

Héno:
Let's close the subject about standard. If the manufacturers are not able to come up with a standard, then it is imperative to have an up-to-date documention. The next topic of discussion is epipolar re-sampling and I believe Mr. Loodts has specific requirements concerning epipolar re-sampling so it would be better if he talks about this.

Loodts:
Epipolar re-sampling is an important process in order to create a stereo model for plotting. It is very often necessary to transfer a stereo model from one plotter to another. For example, I did epipolar re-sampling on the Intergraph station and tried to transfer the image to another machine, but I never succeeded. I have tried to do it with Vision as well, but it turned out to be a very lengthy process. The problem is that there is no clear documentation; you do not know where the coordinates are and where the epipolar transformation is because Vision does not do epipolar transformation, they use polynomials, and I could not understand everything.

Madani:
I cannot speak for Vision International or others. When you talk about epipolar rectification, there are two things happening. One is the algorithm itself, which is the mathematical rectification or resampling process and the other one is the raster format. When you said that you could not load epipolar imagery generated from Intergraph station to another software, then there must be a deeper problem. Loading is just a matter of reading the file. I think if they cannot use our raster, COT, JPEG or other formats, then that is their problem. But when you talk about epipolar rectification then you are not talking about a mathematical rectification. Thus, reading the exterior orientation parameters, applying the rectification by bilinear resampling or using a convolusion should not give problems; all these processes are well documented.

Becker:
The problem is quite clear to me because the COT format is not that open. I have tried to look for it in the Intergraph World by WWM, but you do not get the necessary information. So it is also up to Intergraph to give other vendors the information about the proper file formats.

Madani:
So the raster format seems to be the problem again. So what we suggest is to use everybody's format, change it to our environment and use it in our application from A to Z. When you talk about using our format, its either you have to do the conversion for which we offer the utilities; it converts a COT or JPEG format to a TIFF format, although TIFF has many different formats, or you change it to a raw format and use it in your environment. Yes, it is true that we do not provide an open system for anybody to use our raster format, but there are utilities in our environment that will allow you to

change our formats to either TIFF, untiled TIFF or raw format and use it if your system can read it.

Loodts:
If you speak about TIFF, there is no problem, you can effectively convert to TIFF. But then you do not have a direct link to the coordinate system.

Roth:
Mr. Loodts, I think we are getting to the same point like with the transfer of the orientation parameters; it is not sufficient to dispose on the raster format in a standardized form. If you have a TIFF file, you can read it somewhere. Perhaps it takes too long then take the tiled file or use a raw format; but to provide all the transformation parameters which are necessary for the epipolar image resampling as you want it is much more critical. The critical point is to really have standards for the orientation.

TOPIC: Access to System Libraries as Development Tools

Héno:
I would like to suggest that we discuss the problems of DTM extraction as the next topic. What is necessary is to be able to import and export a DTM. It is very frequent that you do not use the same software from the beginning of your process to the end, as we do it at IGN. We have our own correlators and we would appreciate it if we could import this correlator into a standard software. Image processing is of great importance as far as digital photogrammetry is concerned. Like Mr. Loodts said this morning, it would be good to have a development platform to enable to build ones own tools since those provided by the manufacturers do not always meet your requirements for your specific applications. It is definitely necessary to have an open platform to be able to process the images and to be able to import and export the results from one image processing software to another. Are there any comments on that topic?

Loodts:
I have a lot of experience in this field. I believe that a number of companies like Eurosense developed their own image processing system as digital photogrammetry came up later on, we also have our GIS systems. We will not change our image processing system because digital photogrammetry equipment is now coming up and we have to live with different configurations.

Tempelmann:
Especially for image processing application, I do not see such a big problem because what do we really have to exchange between our DPW work stations and image processing system are only the images. We have a problem with the image format, of course, but as soon as we have a common standard

between our system and the image processing system, then all options are open. Meanwhile, it is possible to have access to the internal functions of the digital photogrammetric work station software as it is available in the Socet Set tool kit. You can even use a number of image processing utilities; you can also use the provided functions and additionally, you have access to the internal image formats. So there are two ways to link your own applications: it is either by transferring images or by accessing internally. So what else do you expect us to do?

Madani:
We keep going back to the same thing in different areas. For image processing tools, there are at least 10 or 15 different algorithms in the image processing textbooks which are used for image enhancement, brightness, contrast and color adjustment, etc. For those who have the Intergraph system, if you look at histogram matching and you want to change the image appearance, there are many ways to do that. But if somebody comes up with his own customized map model of which we are not aware of, then we cannot dream of it and make it available. Since there is no standard, we can only provide as much as we can, otherwise, down the road, somebody will ask for something that we do not have then obviously, that would be his problem.

Kölbl:
I am not so sure whether we all have what we really need. I mean the operator wants to see a good image where he can see the details. You spoke about dodging, very often dodging and partial brightness correction is not a standard product in image processing. You should also have other facilities if you want to do orientation. When you work on image orientation, you should not be limited to just contrast changes. So I think, a number of facilities should be standard to assure that the operator has an image which is efficient.

Héno:
Of course, the users are not asking to have all the capabilities to be able to read everything coming from any platform. However, it would be really good for the manufacturers to provide something open that will allow the users to develop their own tools and to get the necessary information which is actually not the case.

Colomer:
I have to say that we have used the development platforms of Intergraph quite frequently. Intergraph supplies development platforms for the GIS, DTM, and image processing functions. Furthermore, for photogrammetry, they deliver some IO routines that allow you to make decompressing absolutely transparent to the user. In this photogrammetric case, the Intergraph environment allows you to add your own algorithms and integrate them as a push button routine and generate an intergrated menu. If you want to go somewhat deeper into the system and interface with the real time loop as we have done once, then that is another story. Frankly, I understand that all the manufacturers are not so willing to open to the users the deepest level of

the program because it is a great risk. And I think to some degree, the vendors have to have the freedom to change the core of the system. So far, this is our experience relating to this topic.

Loodts:
That is also one of the reasons why I have developed a lot of tools on my own. Under ArcInfo, there is no environment that you cannot modify, you are able to customize everything and you can access many libraries.

Madani:
As Mr. Colomer said, we provide many capabilities and platforms to the users, but not too deep so that users can independently do whatever they want to do from A to Z. For example, when it comes to image processing, we have an image library which is open to anybody who wants to write his own software on image processing. But then you cannot go all the way. We have to maintain something to secure the system. You cannot go all the way down to anything you want, but this is a problem we always have. No matter how deep you go, we have provided the library for all the routines which you can use for image processing.

Colomer:
It would be ideal to have OLE (Object, Linking and Embedding) type of tools for inter-application communication. But this is going to be very tough and complicated. I think nobody will say that OLE is easy to program. So I think we have to lower our requirements a little bit.

Madani:
When you speak of extended OLE standard, Intergraph went beyond what Microsoft has done so far. As Intel and Microsoft almost dominated the computer technology, at least a market share of about 90% or maybe more, we believe that these standards have an importance. Some of you may know that this year or the coming years, Intergraph will be on the Microsoft environment. In that environment, you can work with applets. You can grab those applets, combine them, customize them, and you can put them in Word document, Excel spreadsheet or whatever you want. There is no application designed in advance and the main functionalities will be written in the applet environment. This applet environment will allow the customer to choose or use package applications according to their wishes. I do not know what is going to happen and what the general reaction will be. As you said, it might be difficult, I do not know. Again, photogrammetry is nothing in the world of computer technology. We have to reasonably utilize everything that is available.

Roth:
I want to come back to raster standards because image processing that you all want to do is extremely time consuming. You want to do it with your own software which you had developed earlier; of course, nobody knows your format and so you will also have to change your format to a standard format. I think if the software packages will allow direct image processing in a

standard format like TIFF which is well documented then you should not have real difficulties and it should already be possible now. However, you have to be careful in case of time consuming tasks like writing and reading the files. So if you try to introduce a standard, you automatically have some limitations. The question is, will you accept a time consuming, real time, direct change of the format or would you like to do a data conversion prior to your image processing?

TOPIC: File Management, Visualization and Real Time Zoom

Colomer:
I think we have to move faster to the next topics. We have covered more or less the IO routines and interfaces. In this case, I recognize that some of the general requirements are a little bit redundant. Interfaces for existing built-in functions of the systems, I think we covered. Interfaces with image processing platforms are more or less disclosed. I think we have already discussed the autonomous processing concept. This concept of workflow automation, I think has not been fully discussed. I have seen the vendors and manufacturers provide some type of integrated application software at least for editing DTMs. I have also seen at least a couple of softwares that allow you to modify a point so that you get the control immediately. Then this support database and project/job management tools are very specific requirements. Personally, I think that such tools can help us tremendously in organizing all the small individual files. The idea is to put all these files into a relational database. It is not flexible, it is not an ASCII file, we should probably scratch this because I have heard that everybody wants ASCII files that are easy to access. So if I propose to have an Oracle or a database interface, you might say that I am a crazy man because of the cost involved in this and it is not so easy to handle. But be aware that it's somehow risky to edit directly an ASCII file so I think this point is very specific and I will defend it. For a big organization it is an issue. We should jump directly to the display and start talking about the ergonomic problems. This is a very important aspect, especially for those who are doing stereo plotting, so I think now is the right time to define some of the minor requirements for visualization, if you agree? The first point is the real time interpolated zoom, any comments? Matra has this intepolated window, Intergraph can interpolate in this sense as well and I do not know if this is perceived as a non-issue, mandatory or beneficial. Are there any comments from the floor?

Madani:
As you very well know, we have on the UNIX, integer and non-integer zoom capability. However, we do not have and I do not believe that any vendor is going to have an environment allowing a real time zoom. When you are in the stereo re-sampling and roaming process, we provide you either an integer or non-integer zoom based on the ratio factor you choose. When you are in

that environment, then you can collect your data, but you cannot change the zoom factor in the middle of that collection process.

Roth:
I think it is the hardware that enables you to do real continuous zoom and roaming at the same time because you need from the hardware the graphic interface. If you try to do it by software then you can just forget it because I think the zoom steps are done very quickly just like image pyramids or simple re-sampling in the graphic interface. You have to do it very fast because you do not want to lose any time in the display of the raster images. If it is a real requirement that everybody wants to have, then you have to really think about the hardware environment that you have at the moment and see how that will be developed in the future. I think on the UNIX work stations, which we sell as a vendor, but we do not build them like Intergraph for example.

Madani:
For what you just said regarding the existing system, yes, this is all we have right now. But in the future, depending on the power of the computer system we plan to have that kind of capability, although I cannot promise anything. If we have the power and the users are willing to pay for that power then we are going to provide that zoom capability. The other comment that I want to make concerns the "simple ASCII files" within a relational database for photogrammetry . We are spending too much time exploring Oracle, Inform X, Ingress and so on. As an example, when we implemented these relational database into our system, we had problems with those ordinary operators who were totally unfamiliar with this technology. They were used to working on the analytical plotters for 30 years and then switched to digital photogrammetry. All of a sudden, they were faced with a relational database and they were completely confused; therefore, we removed it from the system and then we provided them with ASCII and binary files. We spend so much efforts providing many things.

Roth:
Mr. Colomer, I would like to ask you something. If somebody is doing normal mapping and data acquisition with the SD 2000 on the analytical machine, as an example, how often will he do continuous roaming? or perhaps very often during one measurement because that is the real issue. So the question is, are zoom steps really necessary? How do you want to get them? during the measurement? Because I think that on every work station or stereo work station, you can do it in the steps, the interpolated way that you can have during the measurement automatically, zoom and then finish your line; this is not a problem. How often do you want to change the interpolation factor?

Colomer:
My point is not about continuous zooming, it is about maintaining smooth roaming while displaying an interpolated image.

Kölbl:
From the operator's point of view, I have the feeling that it would be important for him to never lose the image when zooming. When the image is erased and it comes up again, then the operator has forgotten where he wanted to measure his detail which is a real drawback. Of course, the use of windows is a certain help and you can refer to the neighbouring one when necessary, but that is still not the ideal situation.

Madani:
Perhaps the question was not very clear when you said real time, is it the continuous zoom? We obviously understood you differently. As you well know, we have in Intermap analytic a dynamic zoom, not only you can change the zoom as you go along, but you can also change the illumination of the floating mark, illumination of the stage, as well as the illumination of the floating point. When you said real time, we understood that while you are scanning and roaming, that you want to change the zoom factor. However, if you are talking about integers versus non-integers interpolation, we already have it. You said you can change the zoom at any level you want to, and do not forget that you have the referential screen.

Tempelmann:
I believe this is not the time to think about continuous zoom because we still have to wait for some hardware improvements which are coming. Graphics which is fast enough to allow for real time interpolated zoom should be available soon. At the moment, it is really impossible to do something like this, unless you want to pay an enormous amount of money for your system. It is the same scenario with image roaming as we are using the same hardware. Getting graphic cards which allow pixel shifting was a problem until last year, but all the developments went into CAD requirements; they can do very fast shading, but not fast shifting of the image. Now that the multi-media applications are coming, we are lucky. Pixel operations are once again supported. For example, The Creator Graphics from Sun Microsystems is very promising and we hope to get all this into Socet Set, but we have to wait for better graphic cards.

Colomer:
I raised the question on smooth roaming because I know of one system that is not present here in this manufacturer's forum that is only devoted to stereo plotting with nearest neighbour interpolation. This system has no DTM extraction, nor triangulation and is only devoted to stereo plotting; in addition, this system only has nearest neighbour interpolation and small jumps while roaming. When you approach this manufacturer and say that there is a lack of interpolation, bilinear or cubic convolution, etc., then their answer is that "you just scan at 30 microns and fly a little bit lower." I raised the question here because if you want to do stereo plotting, there should be no problem in vizualization and zooming. This system only allows you to zoom 2 times because there is only nearest neighbour interpolation and you begin to see the pixel. Do you understand what I am trying to say?

Madani:
To give you an answer to this question, as far as Intergraph is concerned, we provided a smooth roam, a fixed window with kings move, static window with or without pan and we have all the possibilities including the real time zoom, interpolated and bilinear interpolated zoom. Again, this is the maximum one can get in one system. We provided 3 or 4 different approaches to scan and digitize a model. There are many options to choose from, it now depends upon your needs, requirements and money. I do not think everybody else has all these options available in one system besides Intergraph.

Taft:
I just want to give one final comment to that. I am sure that Intergraph must have learned the same way we have learned. You can please some people most of the time, but you cannot please all the people all the time. We just have to do the best we can and hopefully, the customers will feedback to us in sufficient time what they want and what they agree they all want. Then we can actually try to satisfy, let's say nearly all the people.

Madani:
I have one more comment. What we heard here indeed represents a forum between vendors and users. It is just true human nature to raise all the troubles and bad news about a system. But you should also admire or give credit to what we have done and accomplished so far and that you are using it without any difficulties. You can easily take one bad example and exaggerate it somehow because you have the right to do so. Ultimately, if we want to achieve something, vendors and users must have an on-going open communication. We will undoubtedly progress in that fashion and come up with a better version of the software. However, we should at least see and recognize what we have done properly and keep those options for the next generation instead of deleting all the good options.

Colomer:
Again, if you are to buy a system, would you put on the specification the need of interpolation or would you be satisfied with the nearest neighbour interpolation? I am not complaining about Intergraph, but as a user, would you want an irrational interpolated zoom function or would the nearest neighbour be enough?

<u>TOPIC</u>: **<u>Recommendations for the follow-up of the logistic aspects</u>**

Héno:
We will close the subject. What we are going to do aftewards is write down everything that has been said about the topics and maybe remove some unnesessary parts. If you have something interesting to say, please let us know so we can publish something as interesting as possible.

Kölbl:
The proceeding of this workshop have a very strict time table. All the things you want me to include should be availalbe by the 15th of March. We have to supply the manuscript to IFAG by end of March and you must understand that this will be a hard task. Would you agree that we write down the discussion as good as possible; I do not intend to send it to you prior to publication, although the vendors especially might be somewhat sensitive. Can we agree with these suggestions?

Roth:
I think if we want it to do it the right way, normally the vendors should write down the comments about all the points to make sure that we fully and clearly answered the questions and comments because simple discussions does not allow deeper reflections. The real question is now, shall we do so or not?

Madani:
I would like to just comment on that. These last two days, we heard about the "wish list" and "desires" and we were limited to one or two questions, we did not want to drag the sessions back and forth between users and vendors. At least from Intergraph's point of view, we did not say any word until today. You raised questions and comments, you used some of the comments without understanding the question–how it was posed or how it was answered. We should at least see the comments and have the right to comment as well.

Roth:
We should leave the requirements as prepared and it would be better not to have comments from the vendors. Just let us take it as requirements from this group. I think I am speaking in the same sense as Mr. Madani. Either we leave it as it is perhaps there are few points just arriving and just put it down on the list, but then just the requirements, if that is enough.

Madani:
When I regard the question and the column concerning the comments of the users, I would like to say the following: obviously, users are using different materials, systems and intrument from different vendors, therefore, they have the knowledge or experience about a particular system. As long as they use it properly and have proper comments about it, that is okay. We have here a balance of different vendors.

Taft:
I think the main question is, what will be done with the transcription of the meeting? We need to agree on standards and how do we arrive to that? As far as I am concerned, speaking as a vendor, I am sure others will agree that we have been honest and that we have answered the questions and have given our points of view. So I do not see any problems with anything we said being published, providing the document states at the beginning that it represents more or less the "minutes of the meeting," what was discussed, how it was said and in what frame of mind it was said. It should not be put

down as a definitive document about this system and that system and which system does this and does not do that. It has been a fairly open discussion which is good, that was the whole idea of the meeting. I am glad that it has been that way, it has made it worth while. The framework of the meeting has been to have a good discussion. We have all been honest to each other, as far as I can see, so go ahead and publish it, but at the beginning of the publication, it needs to state as to exactly what the meeting was, how it took place and how it was said.

Chapuis:
I agree with the statement, but on the other side, I must admit that all these requirements are representative for the budgetarity of all the users. I think we have here some important users which have participated in this symposium and I think all these requirements have to be considered as "wish list." If the industry wants to make a move, we have to have a broader base to be able to take actions. Secondly, it is a general remark, we have been talking about standards and so on. I have the impression that when the programs or systems are already out in the market, we are going to start talking about standards. It seems that it will not wear out. Perhaps we should have in mind the next products that are coming to the market. I think we now have to start to talk about formats, standardization and so on, but that is all.

Kolbl:
I am grateful for all the vendor's statements. I would just assure you that this workshop will mainly show to many other potential users that digital photogrammetry is now in the stage that it can be used and that digital photogrammetry is replacing older technology; this is the main objective. I assure you that we will, of course, try to write everything down as it was said and meant. I will read it, but I will not put something into this discussion which was not meant. The main idea is that we should encourage the use of digital systems. The next step should be to sit down and to work out the standards. By experience, I can say that if I send you all the discussions, we would require at least 4 additional weeks after the transcription. Therefore, can we agree, as you already suggested that we write it down in this sense, that we avoid statements and only put what we consider as wishes.

Colomer:
I think we have homework to do in the next 3 -4 years about the standards. Those requirements were only formulated by a group of three. It is not by any means reflecting a wide spread, questionnaire distributed to a lot of organizations. Let us follow the way Prof. Kolbl has suggested, we will write the "minutes of the workshop" and probably eliminate some redundancies. Remember that this is prepared to be sent to everybody. This was just a draft, a guide for the discussion.

Madani:
As far as Intergraph is concerned, we have no objections with the format which you are providing. As I said, this is a small sample, it does not cover the whole population of the photogrammetry users, but it just points out a view of the people who are here. If you pass this information to another group, they have their own different views. Secondly, I want to give a comment concerning these requirements which all of them are good to have. At least we should have some kind of balance between those systems which have these functionalities, rather than pin-pointing to the bad things. What I am saying is that we have to cover the whole spectrum of digital photogrammetry systems in different work flows rather than saying, "once I ran this software, the system crashed and the system is not working anymore," it should not be that way.

Loodts:
For the first time, it is good to finally meet all the vendors together. We believe that we have a lot of experiences; we already had a lot of discussions together and collectively agreed that we have some problems. The idea of this group meeting was to share and express our problems. And I hope that we succeeded in showing you some of our difficulties. We are grateful and thank you very much.

Part 7

Financial Aspects

Direction :

C. Dekeyne J. L. Colomer

Short note on the economics of stereoplotting with DPSW

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Summary

Besides other technical concerns, stereoplotting with digital technology is questioned in terms of its productivity and costs. In fact, stereoplotting has not yet achieved the levels of automation and efficiency found on digital orthophoto production, DTM extraction and semi automatic digital point transfer. In this short note, we will summarize the experience of the ICC working with seven Intergraph digital workstations in stereoplotting.

1. Support structure

Operating on a computer-based environment means trained personnel for dealing with the initial system setup, testing of new features and software fixes, the development of the methodologies, naming conventions and workflows, and with the critical task of assuring operational continuity by resolving day-to-day troubles. This support averages now half a person/year, but was larger during the start-up period. At this time, the number of software fixes and product enhancements were frequent. As in other computer-based products, the need for support decreases as the software becomes more mature until a major change in the computer platform, operating systems or software architecture forces to start the cycle again.

2. Costs

The factors mentioned above increase the costs of stereoplotting with digital photogrammetric stereo-workstations. The costs are largely dominated by the hardware and software yearly maintenance, the purchase prize for more than one system and by the relatively short amortization period. For the analysis, we have taken seven years for the analytical and five years for the digital stereoplotters. The reason for the five years is our perception that we will change the computer platform to a cheaper one based on personal computers in 1997/98. In the analysis, the cost of scanning, the costs of the structure and the benefits are also included.

3. Productivity and operational costs

On the productivity side, the figures obtained by comparing our analytical stereoplotters with no superimposition with the digital stereo-workstations show an almost equal productivity measured in raw hectares per hour, but a 30 to 40% saving on the quality control and map editing/correcting tasks. By taking the complete mapping task (stereoplotting, quality control and editing), we obtain a 9% difference in operational costs in favor of the analytical stereoplotters.

As mentioned several times, the merit of the time reduction in the editing tasks is not because of the digital technology, but because of the stereo-superimposition. Unfortunately, we do not have access to analytical systems with this feature for comparing productivity. Therefore, it is still necessary to refer to the 30% difference in favour of the analytical plotters found by R. Schroth in his study of 1992.

An extrapolation to PC- based systems reverses the difference, even by taking three years for the amortization period. Equal productivity in raw hectares/hour is assumed also on the PC-based systems: this is, we assume that the overall computer and visualization performance is identical to those provided by the high-end systems. At this point, it is necessary to stress that digital systems devoted to stereoplotting must provide high performance features in visualization ergonomics: smooth continouos roaming, no jittering or artifacts, fast and clean real-time stereo-superimposition, large viewing area, and no penalty in dealing with small pixel images. Without these features, it is quite unrealistic to expect competitive productivity in stereoplotting with digital photogrammetric stereo-workstations. So far, we have had no opportunity to check these requirements on the new Pentium-based digital workstations.

Discussion after the Conference:

Financial Aspects,
by J. L. Colomer

Dekeyne:
We come now to the last topic of the seminar and it is maybe the most difficult one to talk about. We just had some interesting discussions about the functionalities required by the majority of the users. As far as I know, the ICC has the best experience in digital photogrammetry in Europe. Since the IGN is a state owned company, we have the experience and the resources to step into the new technologies, compared with small private companies which are probably more inclined to wait and see. I remember Mr. Loodts talking about digital photogrammetry in the Intergraph seminar in 1992 and the subject was, "Why go digital?" I vividly remember the conclusion which was, "maybe it is time to go, but perhaps it is better for others to go first before I go." One objective of this last session is to hopefully answer some of the questions that we have financially, thus, the questions are, "Is there a return on investment?" "Should we go digital or should we stay where we are?" "What should we be aware of financially if we compare digital to the analog or analytical production equipment?" Overall, I would like to just speak about the "purchase price" in general as the basis of comparison for the AP, GIS, Super Imposition and DPW systems because I am not aware of the prices of the equipment from all the different companies. In fact, I have no idea how much we paid for an ImageStation, but I know how much we paid for the AP, super imposition and DPW systems. Even though we had some ideas of the real prices of the systems mentioned, it was very difficult to prepare the actual figures, because there are some differences in prices even with the same vendors in different countries due to financial conditions, exchange rate, and so on. Regardless of how much we bought the systems for, something more controversial that I would like to discuss is how many years will it take to get your money back or your "refund." How long will it take or should it take until it pays back? In our company, for the old analog and analytical plotters, we used an estimate of 7 years period to refund. So we kept this period of 7 years to refund for the AP, Super Imposition and GIS. And I think it was completely wrong because as soon as we got more hardware and software, it sure changed everything. In the last 7 years alone, we changed our hardware maybe 4 times so this is definitely wrong. The other question is for the DPW system, what is recommended? Like for the PC or work station, it is only 3 years so what do we do? What is the experience? Everybody is expecting new things like new graphic cards to have stereo roaming and so on. Mr. Madani and Mrs. Roth stated that photogrammetry is very small, so I wonder how cheaper or how expensive all these would get in the future? Maybe you can give us some indications. What is the forecast? It is hard to say that if I purchase this equipment today for whatever price and in the next 4 or 5 years, it depreciates at 10% to 25%. I think that we can have an open discussion because this is not a position paper. I would like the vendors to comment on these statements.

Colomer:

About the refund period, we purchased our first digital ImageStation in December of 1991 and we started production in 1993. I do not know what Intergraph's plans are in the future, they may consider to change the ImageStation in 1997, who knows? But should that be the case and the company introduces a new product and technology, then the figure of 4 years for "return on investment"or "refund" is a little bit too uncompromising so I would rather say 5 or 6 years because I think digital photogrammetry will probably come up with a newer technology in 5 years. You certainly have to consider how many years it would take to get your refund. My suggestion is to use Integraph as an example and use the five year "refund" period for digital systems, at least for stereo plotting.

Madani:

First of all, you cannot count by that. Just to illustrate my point, let us say one vendor came up with a system in 1991 and then changes the operating system to another one. The investment gets repaid in 7 years and the other one gets repaid in 10 years–this is not the way you calculate to get to the bottom line. And the second point is when you say that we are coming out with a new generation of photogrammetry solution, it does not mean that you can no longer use the existing system. You can still use the existing system and work in a multi system environment. I am not a financial expert to come up with figures, but I think the basis for a "refund" should depend on how many jobs you can finish and how much money you can earn in that four years period. If you are an extremely successful businessman whose profits in 4 or 5 years exceed his initial capital investment and operating costs, then this entrepreneur can easily repay the system faster than somebody who tries very hard to get the job done and it might take him 10 years to repay the system. It is very dificult to just come up with a number of maybe 5 or 7 years.

Schroth:

Maybe I can give you an answer. If you make a financial analysis, of course, you make some assumptions. One assumption is the depreciation value and you also make an assumption on the amount of working hours per year. But there are parameters which are independent from what kind of project you are engaged in. The average working hours per year must be accounted for and this is very important. Mr. Colomer is giving it a 5-year estimate for depreciation. I think this is the right figure nowadays, but it is changing. If you go back, let's say to the analog systems, those systems operated for 12 to 14 years sometimes 15 years, but of course, not on 15 to 20 hours a day. One of the first analytical plotters that came out, the "C100" from Zeiss operated for more than 10 years, but that also changed. If I go to the next generation of analytical plotters like the P1 or Intermap (IMA), you can see for example, for IMA that it only operates for maybe a maximum of 8 years because the vendor is running out of processors. Like for Intergraph, there you have the big difference in the software version for Microstation, therefore, you cannot operate it for 100%. The next step in the digital photogrametry would be that you can operate your work stations on an average of 5 years nowadays. I think, if you look at the time period now, it is shortening and the expectancy of different systems in the private industries will depreciate in 3 to 4 years. Additionally, if you check the taxation bureaus in different states, they now accept 3 years depreciation for computers. And you know, they want to tax you quite a bit so if they go down to 3 years, there must be a good reason for it. This is my comment.

Everaerts:
I think the other problem with the soft copy systems is that you keep on buying hardware and that you cannot keep running the same system for 5 years. You have to take into account the costs of upgrading the processors, buying new releases of software, buying additional disks and so on.

Roth:
I think that really depends on two points. If I view it from the vendor's side, my first question is, how willing is the vendor to go forward in one direction and either start with analytical or digital, and be able to support all the systems? The second question concerns the size of the systems. We are currently using a standard computer hardware; should Silicon Graphics, Sun Computer or other giants come up with the latest and the greatest computer hardware, then we have to question whether we even get the chance to support the old computers in 5 years? Even if we are willing to do it, will we get the chance to do it? If you are no longer involved in the hardware configuration or in building the hardware, we do not have any system any longer that we can just hook up. Furthermore, I think we will have to see how the situation will change in the hardware platform because we are also platform dependent.

Madani:
To reiterate again what I said, we are dealing with the computer industry. We do not know, and you will never know what will happen to different UNIX operating systems in 3 or 4 years from now. If Intel or Microsoft which are claiming to be the best, completely dominating the entire computer world and we will have such a computer in every household, we cannot predict what will happen afterwards, I do not know who will survive after that. Also from Intergraph's point of view, I am obviously not the top executive of Intergraph, but we are also faced with some dilemmas, and we are looking at volumes of product applications. Photogrammetry is a very small market, and fortunately, they are very conservative people and they do not want to change the operating systems. As long as the functionalities of the software is there, they do not care if it is UNIX, Microsoft, VMS or whatever. The problem from the vendor's point of view is that they also have a business to run, they cannot say that if Mr. X is not getting his return on investment, we will have to treat him differently. Intergraph is also looking after their business and they have to. You never know what will happen in the computer industry, therefore, we do not know what will happen in the photogrammetry industry. And then as you said, Mrs. Roth, that you are dependent on the hardware platform. Digitally or analytically, photogrammetry's functionalities of the software are almost a straight

forward procedure. The only exceptions are automation and correlation techniques which are in the domain of photogrammetry, we are taking care of that because you are using them. If you go to the computer vision industry, they are ahead of us. They are doing all kind of things which we just started doing. They never mention the word photogrammetry and they can do a much better job than we can in animation, pattern recognition and many other things. In any event, I am not a business person, so I do not know how you came up with the formula in order to satisfy your expenses.

Becker:
Another aspect that we all should consider is, what are we going to do with the old analytical machines? Absolutely nothing. However, what you do with the old computers, well, there are other application for it. What we used for our CAD four years ago, and it was the most powerful CAD terminal at the time, it is now being used by our secretary. So there are other uses, secondary uses for a standard hardware for users which in the long run, you can give it to the programmer to use as a dummy terminal, you can use it as a file server, you can use it for all sorts of applications. It is not a piece of hardware that becomes totally useless and have to throw away. There is a second use for these computer equipment if it is more standard.

Madani:
As you said, it is a very simple answer. In the analytical side, at least we know with the collaboration of Zeiss, what the "cadillac" was or the "top of the line" analytical plotter was at that time and it had all the things that anybody could ask for in the analytical domain and because of VAX etc., this line, however, is dead now. If a smaller company is willing to survive, they can do the job using that kind of instruments. But if you want to go with the flow, you have to see and adapt to what is going on out there in the market.

Roth:
I think there are two kinds of users. There are users who like innovation and they will acquire everything that the new technology has to offer. What I see at the moment, also from Intergraph's side is to push this new direction. In our case, I see to handle our business market in a way that we satisfy all the customers not just the ones who have the up-to-date equipment, but also the ones who still want to use their SD2000, C100 or something with the new Microstation software because the instruments and PCs are still working and available. I think that there are many people who do not want to throw their PCs away just like keeping their old analytical plotter. Like you said, even though it is an old operating system, it can still do the job. What we have seen in the market is that there are still many C100s out there on the HP computer and they are still really working and doing the job. They are not the type of users who will go for the newest technology, they will update their equipment somehow for whatever reason later on. It is like working on analog instruments, where you are digitizing with Microstation. I think we ought to take a look at the percentage of other companies working in that direction.

Becker:
If you buy the hardware, you will make use of it and you will not just throw it away. You will use it until you cannot do it anymore, but if you have a standard computer, you might not throw it away.

Schroth:
I cannot agree that you can use your PC after 3 years and just give it to your secretary to use. I cannot imagine giving our secretary my ImageStation–she will kill me. But if you are working in a production environment, that means 2 shifts per day, your PC along with the monitor, keyboard, and processors are normally 3 years off completely and I do not believe that you can use them for word processing anymore. I believe, if you are a service company, just like MAPS or Eurosense, that you must earn your money first, independent from what kind of technology you are using, old or new technology which ever fits your company and which ever gives you the most profit. I think we can all agree on this. Therefore, the decision is heavily influenced, not only by future developments, but also by getting the money back for your investment; this is one of the factors why we go in this or that direction. Of course, it is important to deliver what the client wishes, that is one of the main points, but we have to earn the money, we have to show that the investments bring in some profit for shareholders or whoever, and the same goes for the vendors as well. Just look at the amount of analytical plotters which are still on the market which are sold by these companies. I believe companies who are selling both types--digital and analytical plotters, I do not know the figures of Leica or Zeiss, but I can imagine that it is nearly similar now or maybe more analytical than digital plotters. Maybe the vendors can tell us something about their trends.

Roth:
I think if we see it from the last 2 years, we are not really at the breakpoint yet where digital is all over more than the analytical, but I think nobody can say when what can happen. We have to talk after the Congress once again because to me it seems that many companies will look forward of getting more information about the new ideas or innovations.

Chapuis:
In fact, the number of analytical systems sold today are still increasing, but on the other side, the proportion between analytical and digital systems is about a 1 to 1 ratio.

Eidenbenz:
I would like to give you an example out of our office. We bought in 1984, a Sitec System which we upgraded in 1986. We spent about 2 Million Swiss Francs and we had a task to do--that is contour line extraction out of the 1:25'000 scale map. We will finish this task at the end of this year and the system is still running. I do not know what kind of operating system or revision number we use, but they are on HP computers. Sitec stopped cartographic development completely, but they still maintain the system for us, but there we have a problem. They really got us as for the maintenance

fees. The system runs, it does what it is suppose to do, but there is no development going on. We have everything that we need for our task, but the maintenance fees are very high. For the amount of money we are paying for the maintenance fee, we could easily buy 2 work stations per year.

Adam-Guillaume:
It is not good to look for innovations too early, my company was built on the ashes of another company. So I think that the remarks about the duration are very pertinent and you are obliged to do so even if it does not sound right. Only for fiscal reasons, you should consider 4 years according to the recent French regulations. But this is practically impossible, I mean we have to be careful not to change the computers too quickly. There is also another problem. We cannot predict what our turnover will be; will it be the same next year or 10 times higher? especially now in France, it is not so easy to say. So we cannot forecast like IGN for 15 years. Our situation is different, but we definitely have things in common. We are here more or less to make a profit, but the amount of time at our disposal is not the same for all.

Madani:
The vendors have different ways of looking at these problems. For example, one vendor only has digital photogrammetry system, the other vendor has both and the other vendor only has analytical and nothing else. Therefore, the situation is very difficult to just come up with the numbers. I do not know how to answer this big question. They say that every 2 years we have to account for the new technology in the computer industry because it is the life span of the computer technology. The reason why we got into the situation as Mr. Colomer said is not clear from the programming and business management point of view, at least in the United States, you cannot survive in the computer industry with that kind of management style which started in the 80s. Now people are coming out with some software and application tools. You cannot spend, hire people and develop some kind of product which you can sell for a few years and then have them on a maintenance contract and they pay for the salary of the employees. The trend is Intel and Microsoft. We thought that was a radical decision, but we are hoping that we will succeed in that area and at the same time they have to stream line their applications in photogammetry. Intergraph's photogrammetry division has about 14 to 15 products. The management cannot stand it anymore to have so many products; they have to consolidate these products which would encompass maintenance, support, documentation, and development. We have to stream line them in a work flow product. If you are a business man and you are selling a product for let's say $500. each and you sell hundreds and thousands of these $500. product, of course, we will not do photogrammetry anymore. Why wait for 5 or 10 customers and bargain on the price if you can sell thousands of softwares to many other customers. I do not know what will happen in both the photogrammetry and computer industries, but many things are changing and we are working hard.

Colomer:
We have always been on the "bleeding" edge and not on the "cutting edge." I have an example; look at ArcInfo, they have the leverage on the UNIX platform. They are quiet, peaceful, and advancing based on UNIX. I am not

critizing on the Intergraph's decision. I do not know whether it is a good long term decision to go with Intel and Microsoft, but at least there are other options available. It is not exactly true that if you change your operating system that the functionalities will remain the same. It is not true. There are a lot of work stations that are relying on shell scripts and batch queus. Where are the batch queus on the NT which are the shell scripts? We have to start looking at 3rd party vendors for the supplement. I have always felt that if you choose a technology and a vendor that you are in the same ship with them. This is a partnership. If the vendor suceeds in his technology then maybe it will benefit the users so let's see what happens. We will jump into NT and we will start doing it when you have something on NT. It is just unfortunate that Mrs. Torre will have to re-do everything again. I hope that Microsoft and Intel will succeed.

Dekeyne:
I want to warn Mrs. Torre ahead of time because we have some experience of migrating from one system to another. It was not in photogrammetry, but in the field of GIS where we moved from the Intergraph Tigris work stations to a GIS on PC. For such companies like the ICC and the IGN, we are not developers, we have to make the tools, so we have some training, but we are not computer people. I just want to warn you that if you know how to program UNIX and you have to switch to Windows, be very careful because it is crazy. It is completely different. I am afraid that going to PC will emphasize the problems of tool boxes and micro languages. You should ask yourselves these questions, how standard the functionalities will be? and what will be the developing tools given to the users?

Madani:
I am not in any way in a position to comment, but as a billion dollar company, I would think that they probably made the decision to go from one operating system to another for reasons that are fully justified. Intergraph is very big and photogrammetry is just a small piece of it and maybe they are looking at something else, I do not know. This technology concerning object oriented programming is a good revenue coming from other applications. I do not know if it also applies to photogrammetry. We had the same problem and we had to go through these phases of different operational systems; we started with VAX, then UNIX, and then with others, so we already had the same problems earlier.

Dekeyne:
The next topic I want to talk about is maintenance. Most of the companies dealing with photogrammetry want to have some maintenance guarantees for all the analytical plotter system. Of course, when we go to another technology, this new vendor will say that maintenance will not be a problem. I really would like to know what will happen in 5 years from now because like what everybody said, there are still many analytical plotters out there that are fully functional. How much will it cost to maintain our systems?

When making abstraction of these academic institutions, one gets a surprising uniform image of the used digital work stations. Most of the cited institutions use either Helava or Intergraph. According to this survey nearly thirty Helava and Intergraph work stations have been located. Other firms are much less represented, only 2 Traster work stations and 1 Zeiss work station were located. Evidently we did not succeed to make a completely objective inquiry and were unable to locate the various PC photogrammetric work stations like DVP, ISM, Vision etc. But from the 13 member countries of OEEPE, 10 national mapping organisation responded to the questionnaire, but none of them claims to use PC-based work stations.

According to this survey, most of the cited private firms use only 1-2 digital photogrammetric work station; an exception is Eurosense and Cicade in Belgium which even use 4 stations. Nearly all of them already have experiences with analytical photogrammetry and currently use several analytical plotters in parallel. The national mapping institutions mainly use analog and analytical plotters and only few digital work stations. An exception is the Cartographic Institute of Catalunya, Spain, which uses 8 digital work stations and only 1 analytical plotter. An important production on digital photogrammetric work stations has also the Ordnance Survey of Dublin with 9 digital work stations; IGN starts production with 5 stations and the National Land Survey of Sweden with 4 stations.

3. Main Applications of Digital Work Stations

With the tables 2-4 it was tried to show the main applications of the work stations. According to this survey one realizes that the most important activity is the production of orthophotos and mosaiquing. Most probably this is the primary reason for an institution to engage in digital photogrammetry. An important activity (≈20%?) is also the automatic derivation of DTMs. The Helava work station and the Intergraph ImageStation are equally concerned by these activities. For aerial triangulation and for mapping, one realizes that up to now, mainly the Intergraph ImagesStation is used in practice. The ImageStation is also quite heavily used for the visual determination of DTMs.

4. Evaluation of the Digital Work Stations

The most delicate enterprise in that survey is most probably the evaluation. It is understandable if one reads from the tables that practically all users are satisfied with the stereo presentation on the Helava system and some minor critics come up for the ImageStation. The Helava system disposes on a polarization screen which give a very stable image whereas the ImageStation uses the Crystal Liquid Eye Glasses. On the other hand, the Helava system, depending on the hardware configuration might show delays in roaming. But according to the previous analysis, only the ImageStation is used to a greater degree for plotting requiring continues stereo vision.

5. Conclusions

It is hoped that the presented survey on the "Application of Digital Photogrammetric Work Stations" gives a small idea on the increasing use of digital techniques in practice. This small study should complement the reflections, given by the Workshop, by some small statistics. It is understood that at the Workshop, institutions with great experiences in that field took the word. But one can state that the digital technique is already very wide spread and practically the exclusive tool in orthophoto production. DTM applications are also more and more used in practice and finally, digital techniques also enter in competition with analytical techniques.

The survey mirrors the situation in 1995 and evidently did not take into consideration the new developments at companies now coming up with new material like Zeiss or also in the PC world. It would, therefore, be useful to consider this survey only as a preliminary study; companies, vendors and users are cordially invited to continue to comment this survey and to deliver additional informations. The author is very grateful to all the firms and individuals which collaborated in the inquiry.

	Number of collaborators	Number of employees active in photogrammetry	Total number of photogrammetric plotting instruments	Number of **analytical** plotting instruments	Number of **digital** plotting instruments	
Swissair Photo + Surveys, Regensdorf	90	10	4	2	2	H
Haumann, München	15	12	2	1	1	H
Eurosense Belfotop, Wemmel	180		11		3	H / I
SRT69, Lyon	50	7	3	2	1	I
Politecnico di Torino	8	4	4	2	2	O
Geodis Fotogrammetrie, Brno	?	?	4	2	2	I
Geogramma, Olbia	45	3	1	0	1	I
Nat. Geographic Institut, Brussels	?	22	13	2	2	I / M
Kungl. Tekniska Högskolan, Stockholm	35	9	21	1	17	O
Inst. Cartogràfic de Catalunya, Barcelona	210	70	12	4	8	I
Bundesamt f. Eich- und Verm., Wien	300	50	20	10	1	I
ITC, Delft	350	10	50	4	9	M / O
Ribordy-Luyet, Sion	60	10	3	3	1	I
VLM, Brussels	350	3	1	0	1	I
CETOP, Lausanne	4	4	4	3	1	I
Hansa Luftbild, Münster	150	30	7	5	1	I
National Land Survey, Gävle	900 (3000)	100	36	23	5	H / O
Simmons Survey Ltd, Axbridge	43	8	4	3	1	H
Cicade, Namur	20	15	3	4	4	H / I
INPHO GmbH, Stuttgart	10	10	2	0	2	I / O
Kirchner & Wold, Hildesheim	100	10	5	3	2	I
LHV GmbH, Senftenberg	16	4	3	0	1	I
CHS, Rueil Malmaison	8	6	3	0	3	O
IGN, St-Mandé	2000	200	40	33	5	H
Institute of Geodesy, Warsaw	120	12	1	1	2	I / O
Kampsax Geoplan, Hvidovre	200	150	23	21	2	H
Ordnance Survey, Dublin	250	35	28	16	9	H

Table 1. Overview of the participants of the survey using digital photogrammetric work stations and some characteristics of the organizations. H = Helava/Leica I = Intergraph M = Matra O = Others

1. Main application	main occup.	50%	occasion-ally
Large scale stereo plotting > 1:3000		1	3
Stereo plotting 1:4000 - 1:10000		1	2
Small scale plotting	1		3
Updating of existing maps with image injection	1	1	2
Aerotriangulation with automatic point transfer	2	1	1
Orthophoto production	8		1
Orthophot mosaiquing	8		1
DTM derivation by visual measurements	2	4	2
Automatic DTM production	5	5	
2. Evaluation of the instrument	**good**	**average**	**not satisfying**
Overall evaluation of the plotter	9		
Quality of the screen	9		
Quality of stereo image (Tektronix polarization)	9		
Data compression	4		2
Quality of photogrammetric user interface	5	3	1
Quality of the GIS	3		1

Table 2.
Utilisation and evaluation of the digital photogrammetric work station DPW / Helava according to the inquiry (the figures give the number of users who responded to the criteria).
Number of firms involved : 9 ; number of instruments : 27

1. Main application	main occup.	50%	occasion-ally
Large scale stereo plotting > 1:3000	7	1	12
Stereo plotting 1:4000 - 1:10000	12	4	8
Small scale plotting		2	18
Updating of existing maps with image injection	8	3	8
Aerotriangulation with automatic point transfer	7	4	4
Orthophoto production	21	1	2
Orthophot mosaiquing	9	10	4
DTM derivation by visual measurements	12	6	4
Automatic DTM production	6	2	14
2. Evaluation of the instrument	good	average	not satisfying
Overall evaluation of the plotter	22	1	
Quality of the screen	14	10	
Quality of stereo image (Tektronix polarization)	20	3	
Data compression	22	1	
Quality of photogrammetric user interface	20	3	1
Quality of the GIS	7	11	1

Table 3.
Utilisation and evaluation of the digital photogrammetric work station ImageStation / Intergraph according to the inquiry (the figures give the number of users who responded to the criteria).
Number of firms involved : 17 ; number of instruments : 27

1. Main application	main occup.	50%	occasion-ally
Large scale stereo plotting > 1:3000			2
Stereo plotting 1:4000 - 1:10000			2
Small scale plotting			1
Updating of existing maps with image injection			1
Aerotriangulation with automatic point transfer		1	
Orthophoto production			2
Orthophot mosaiquing			1
DTM derivation by visual measurements		1	
Automatic DTM production			2
2. Evaluation of the instrument	good	average	not satisfying
Overall evaluation of the plotter		2	
Quality of the screen	2		
Quality of stereo image (Tektronix polarization)	2		
Data compression			1
Quality of photogrammetric user interface		2	
Quality of the GIS	1		1

Table 4.
Utilisation and evaluation of the digital photogrammetric work station Traster T10 / Matra according to the inquiry (the figures give the number of users who responded to the criteria).
Number of firms involved : 2 ; number of instruments : 2

Part 8

Presentation of the Systems by the Vendors

Present Status of the DVP System[1]

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Summary

In the few years that have elapsed since the introduction of the DVP, the system has undergone considerable improvements and modifications while remaining true to its original basic objective: to improve and expand the practice of photogrammetry by making it simpler, more flexible and less costly. The DVP system now extends over a whole range of photogrammetry products. There are new and improved orientation and digitizing features. New modules have been integrated in the main system, which now covers monoplotting, stereoplotting from SPOT imagery and orthoimage production. Finally, new packages, including an aerotriangulation package, contribute to the extended functionality of the system. The system has been used for a wide range of applications. With the DVP, a new group of photogrammetry practitioners has entered the mapping industry market and an interesting new tool has become available to surveyors, for topographic operations. These development efforts will have to be matched by an appropriate educational response, in order to optimize their socio-economic benefits.

1. Introduction

When the first operational DVP station was presented, with its standard stereoplotter functions and operations, in *Gagnon et al.(1990)*, softcopy photogrammetry was in its very early stages of development and even the term "softcopy photogrammetry" had just started to be used. Although only a short period of time has elapsed since then, the term has now become commonplace and the technology is burgeoning with activity. As a consequence, the overall picture of photogrammetry is completely different from what it was only a few years ago. During the same short period of time, the DVP system has also undergone considerable improvements and modifications, while remaining true, however, to what was its original basic philosophy: to improve and expand the practice of photogrammetry by making it simpler, more flexible and less costly.

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Canadian Institute of Geomatics, Ottawa, Canada.

[1] *The DVP products are developed and distributed under commercial agreements between:* Laval University, *Ste-Foy, Québec, Can.;* DVP Geomatic Systems Inc., *Charny, Québec, Can.; and the* Leica Corporation *of Switzerland.*

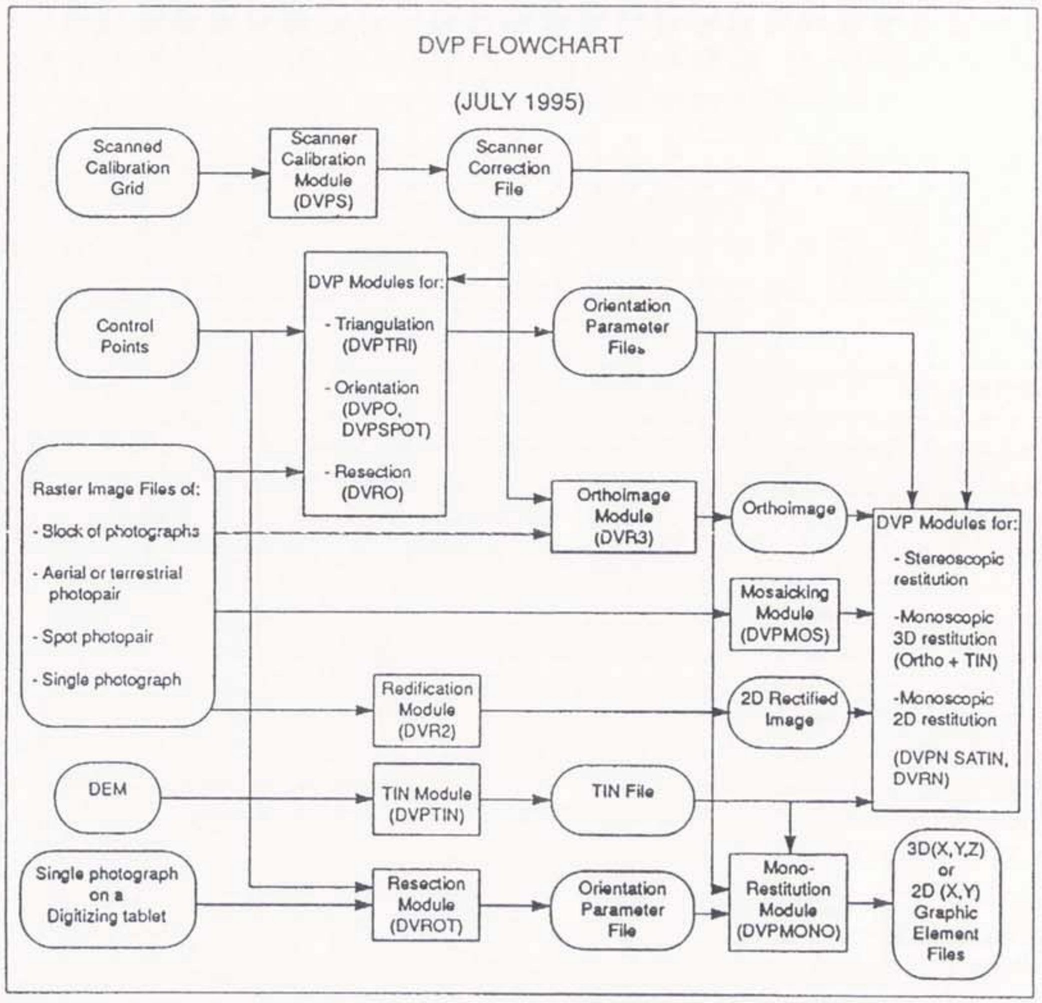

Figure 1: Flowchart of the DVP System

Research activities, new applications and improvements, related to the DVP, have been reported in a number of publications. Among others can be mentioned *Nolette et al.(1992)*, *Boulianne et al.(1994)* and *Agnard et al.(1994)*. The latter, presenting the official OEEPE aerotriangulation results obtained with DVP–TRI, the DVP aerotriangulation package, should have contributed dispelling any remaining doubts concerning accuracy and DVP. On that question of accuracy, it was found that the adjustment to the new realities of the pixel world, for some traditional photogrammetrists, did not come automatically. Being used to equate high accuracy to high instrumentation prices, it has taken some time, for them, to accept the fact that, with digital photogrammetry, accuracy has become mainly a function of the pixel size, no matter the type of platform, provided the mathematical basis is rigorous.

Figure 2: Basic components of the DVP System

There still might be, also, a tendency to automatically equate functionality to high– priced systems. Papers by Welsh*(1992,1993)*, have clearly demonstrated that such is not necessarily the case. The following comprehensive overview of the DVP system, as it stands now, presents a similar demonstration. According to *Heipke's(1995)* classification of digital photogrammetric workstations (DPWS), the range of photogrammetric products is covered by the list he presents: stereo DPWS, used for interactive stereoplotting; mono DPWS, based on digital monoplotting; aerotriangulation DPWS; DTM DPWS; and, orthoimage DPWS. The following overview, summarized by the flowchart presented on Figure 1, indicates that the DVP system now covers the same range and even extends beyond it. It also presents some of the improvements and added features that have been introduced to make the system more efficient and more user–friendly.

2. New and Improved Features

Of the number of improvements and added features described in the technical documentation on the system, the following can be considered as particularly significant: the second monitor, the Popview mode, the automatic and semi-automatic orientations, the calibration of scanner data, and the automatic DTM generation from supervised DEM extraction.

2.1 Second Monitor

The possibility of using a second monitor (Figure 2) has been introduced with Version 3.4 of the main program(DVP-MP). The second monitor can display vectors, imported and/or currently compiled, superimposed on one of the two(in the case of standard stereoplotting) photographs, at the user's desired scale(from full size to pixel size). It also displays different commands and menus. The additional features and possibilities offered by the second monitor constitute a significant aid for many compiling operations, particularly in map updating, providing an estimated potential increase in productivity of the order of 1.5 times. Version 3.4 includes the full set of standard 3D data collection functions, with graphic elements and texts editing possibilities.

2.2 Popview Mode

With Version 3.5, the most important features and functions of the second monitor can be preserved in a single screen configuration, through a "screen on-screen off" function, thus compensating for hardware limitations and constraints that may be met in practice. The main characteristic of Version 3.5, however, is the introduction of a Popview mode in the different orientation modules of the DVP system: in the stereo, Spot, simple and differential rectification, and monoplotting modules. In the Popview mode, the handling of images and menus is accelerated and facilitated by the display of windows.

2.3 Automatic and semi-automatic Orientations

The Popview mode improves processes that had already been made semi-automatic: the interior orientation, made semi-automatic by the possibility of using a camera file to move the measuring mark in the vicinity of the camera fiducial marks; the relative orientation, with the possibility of moving the measuring mark automatically to points of a pre-selected pattern and of using the auto-correlation function at these points; the absolute orientation, with the possibility of automatically moving the mark close to the planimetric controls, once two of these control points have been observed. In the absolute orientation, it is also possible to use the superimposition feature for direct snapping on points coming from an existing map file. That feature is particularly interesting in map updating operations. The output of the absolute orientation includes the camera stations space coordinates and attitudes, which are either necessary or useful in some applications. Of course, when the photogrammetric control comes from an aerotriangulation performed with DVP-TRI, the orientation processes, at the compilation stage, become completely automated, using the output orientation parameter and coordinate files from the aerotriangulation and block adjustment steps.

2.4 Calibrated Scanner Data

In most DVP applications, desktop scanners are used to prepare image files. These scanners, mainly developed for the publishing industry, have not been specifically designed to provide top metric quality. Because of this, with accuracy possibilities and expectations of the order of the half-pixel or better, it is important that, in the transformation of scanner coordinates to photograph coordinates, and vice versa, scanner geometry be properly taken care of. This is done, starting with Version 3.41, by using a calibration file prepared with the Scanner Calibration Package described in Paragraph 4.2.

2.5 Automatic DTM Generation from Supervised DEM Extraction

In Version 3.5, different improvements have been brought to the Digital Elevation Model extraction(the DEM being the collection of the X–Y–Z points defining the terrain): the points defining the fence can generate any type of shape, which is displayed; displacements inside the fence are executed automatically, with operator's pre–defined direction and step; specific functions perform automatic zoom–in and matching at every point, under operator supervision, which makes the operation interactive: points can be added, removed or corrected. The remaining part of the Digital Terrain Model generation(the DTM being the DEM points arranged in a network of a geometrical entity like a square or a triangle), as described in Paragraph 3.2, is completely automatic. This overall process presents a good degree of efficiency, at the present time, considering that, according to *Heipke(1995)*, "...automatic DTM generation in practice still has a long way to go", in particular for large–scale mapping.

2.6 Special Request

In order to accommodate special requests made by some DVP users, the software is now designed to process stereomodels formed by two photographs taken with different cameras and focal lengths. Cases like this are of course very rare in normal practice, and may involve geometry aspects that have to be considered. For instance, with photographs at approximately the same scale and focal lengths considerably different (e.g. 152 cm and 88 cm), space intersection is impossible or weak in the region where conjugate rays are parallel or nearly parallel.

As part of a normal evolution process, and depending on needs and on user interest, new releases of the software will of course incorporate features or options designed to take care of that type of special situations.

3.New Modules

Part of the extended functionality of the DVP system comes from the integration of the following modules in the basic stereoplotting main program: DVR2, for simple rectification; DVR3, for differential rectification;

DVP–MONO, for monoplotting; DVP–SPOT, for 3D collection from SPOT imagery; and, finally, a module for epipolar rectification.

3.1 DVR2

DVR2 basically replaces optico–mechanical rectifiers without being subject, of course, to their well–known magnification and tilt limitations. The effect of tilt is corrected using the classical 2D projective transformation, with the transformation parameters determined by a minimum of 4 control points. In cases where the area is covered by more than a single image, the rectified images are assembled using a mosaicking program. Vectorization of features, on the rectified image or on the mosaic, is achieved with the DVP digitizing module, DVPN. The module has been used for applications in different fields: architecture, agriculture, wetlands mapping, etc.

3.2 DVR3

DVR3 is the module for differential rectification, developed to cover the important present–day needs for ortho–images. With DVP, an ortho–image can be generated either from a single photograph, using an existing DEM, or directly from the stereomodel. All the production steps are integrated and accessible through the DVP main menu. These steps are: model or image orientation, DEM point collection (if necessary), DTM generation, and differential rectification.

If the DEM is available, the first production step for the ortho–image generation consists of a conventional space resection. Afterwards, the DTM is created from the DEM data set and the differential rectification is performed. If the DEM does not exist, it can be produced with the DVP, as described in Section 1.

With DVP, the DTM is formed as a Triangular Irregular Network (TIN). The TIN is created using the Delaunay's algorithm . In the TIN construction, breaklines can also be considered in order to provide better terrain representation*(Boulianne et al.,1994)*.

Once the TIN is completed, the ortho–image is built using the collinearity equations. For every pixel of the rectified image, the equivalent position on the original image is determined. In the case where a stereoscopic model is involved, one of the two images must be selected as the base for the rectification. From the position on the original image, different resampling techniques can be chosen to determine the intensity level to be attributed to the rectified image pixel. The interpolation methods implemented in the DVP are: nearest neighbour, bi–linear and cubic convolution. As with rectified images produced with DVR2, ortho–images can be assembled and/or vectorized using the integrated DVP mosaicking and digitizing modules.

3.3 DVP–MONO

DVP–MONO is the monoplotting module of DVP. Monoplotting, by which digitized map data is directly collected from an aerial photograph positioned on a digitizing tablet, constitutes an interesting development of softcopy photogrammetry. The technique being based on differential rectification, the corresponding DTM and the camera position and attitude have to be known. With DVP, as has been presented above, the DTM can be either imported or directly obtained. As for the camera parameters, they can be either determined by observation of ground control identified on the photograph or obtained directly from the aerotriangulation operation.

3.4 DVP–SPOT

DVP–SPOT has been developed through a joint project between the Canada Centre for Remote Sensing (CCRS), the *Département des sciences géomatiques* de *l'Université Laval* and the Canada Centre for Geomatics (CCG). The mathematical tools and main characteristics have been presented in *Toutin et al.(1993)*. The module enables rigorous 3D collection from a stereopair of Spot raw digital images, with direct access to the basic digitizing functions, for the preparation of the digital map file.

3.5 Epipolar Rectification

A special module has also been developed, to be eventually integrated to the main program, depending on user interest, to deal with cases, in terrestrial photogrammetry applications, where the importance of the scale and orientation differences, between the two photographs, make stereoscopic observation critical. In these cases, after the orientations are completed, the two photographs are rectified along the epipolar axis, at the average scale of the two photographs. Stereomodel computations are performed with the original image files while observations are made using the rectified images.

4– New Packages

The following packages exist at the present time as separate entities. They have not been integrated to the main system because, in the case of the first two packages, users seem to view it as more practical, or because, for the others, the applications they have been designed for are considered as being too specialized. In fact, the last two packages have not yet been offered on the market place, because sufficient user interest has not yet materialized, and in spite of the fact that they have been thoroughly tested and are operational.

4.1 – DVP–TRI

DVP–TRI, the aerotriangulation package, can be used either with analog or for digital preparation of blocks. In the case of digital preparation, the system offers the possibility of complete digital pugging, to tie along as well as across strips. The half– pixels coordinates of tie points are stored into special files in such a way that the same photo coordinates are given to the same point when measured in two different models of the strip. Sub–images are stored when a tie point measured in one strip is to be used as a tie point with another strip. With that, the same image does not have to be loaded twice: first for model formation and second for the transfer of tie points from strip to strip. Digital Dove prisms are also used to help remove residual y–

parallax. Results are automatically prepared in the appropriate format for Space– M adjustment. Using tie and control points model coordinates and Space–M results, a special function prepares the absolute orientation files for DVP processing. As an option, x and y photograph coordinates files can also be produced for a bundle adjustment. In a production environment, the single orientation operation, placed in the hands of a senior technician, at the aerotriangulation stage, offers a significant efficiency gain. It also means a gain in accuracy, because the quality of the final results is no longer affected by the random errors of the usual second orientation operation.

4.2 DVPS

DVPS is the scanner calibration package. It produces a scanner look–up calibration table (LUT) that is used by the DVP. The LUT is constructed from a calibration grid (provided with the DVP). The grid, drawn on a polyester base, consists of a matrix of 24 by 24 black rings with one–centimeter spacing. The position of every grid point has been precisely determined using an analytical plotter. For every scanned point, the center of gravity, expressed in sub–pixel units, is automatically determined using a simple thresholding algorithm and a weighted mean. Using a 4–parameter coordinate transformation, a correction table is built, and it is used, thereafter, in the DVP for all scanner to photograph coordinate conversion and vice versa. If a previous calibration exists, the program compares the discrepancies between the two tables and sends a warning signal if they exceed half a pixel. The whole process taking less than 15 minutes, the calibration should be done periodically to control the stability of the scanner.

4.3 The Digital Video Parallax–Bar (DVPB)

The DVP system has evolved as a by–product of what were, at first, merely educational considerations and concerns. Originally, what was sought was a means of improving the learning process related to stereoscopic pointing and accuracy, for students taking an introductory course in photogrammetry. The idea led to the development of the microcomputer–based method presented in *Agnard & Gagnon (1988)*. Considering the wide gap between that first step and what the DVP had become, it was felt that softcopy photogrammetry, based on the DVP concept and exterior presentation, could provide an additional, simple but useful, tool: the Digital Video Parallax–Bar, which has been described in *Agnard & Gagnon (1994)*. The system is very user–friendly and overcomes the classical difficulties encountered by users of a conventional parallax–bar: the lack of stability of the floating–mark dot while making a measurement. Determination of vertical–object heights, with the program, has been shown, in the above paper, to be in close agreement (of the order of a quarter of a pixel) with values obtained with the DVP.

4.4 DVP–FOR

DVP–FOR has been developed as a softcopy photogrammetry system for large–scale forest inventories. Its output includes a tree plot diagram, with tree identification, species, height, crown diameter and condition. It has been developed in order to overcome the prevailing scepticism, reported by *Spencer(1987)*, about the accuracy potential and the efficiency of photogrammetric methods in forestry and, in particular, for large-scale forest inventories. The features of DVP-FOR and the results of the tests performed with the system, which have been presented in *Gagnon et al.(1993a)* indicate that the system can provide the level of accuracy, efficiency and operationality foresters are looking for.

4.5 DVP-GPS

DVP-GPS has been designed as a GPS mission planning aid, to facilitate the production of obstruction diagrams at prospective GPS sites. Because satellite GPS signals cannot penetrate obstacles such as buildings or trees, these obstruction diagrams become essential tools for the planner. In practice, the obstructions are surveyed by compass and Abney hand-held level. The operation can be time- consuming and costly. With DVP-GPS, the survey is replaced by a stereoscopic model investigation. To make this possible, a "floating cone", representing the usual sky observation window, is injected into the stereoscopic model. This virtual cone is represented as a wire-frame model composed of a user-defined number of rays, converging on the GPS observation site and of a certain number of concentric circles. All objects higher than the cone surface are considered to be obstacles and must appear on the satellite visibility plot. In the presence of obstructions, the cone rays that are lower than the obstacles are raised like floating lines. Afterwards, by recording the azimuth and elevation angles of these rays, obstruction contours can be automatically generated. With this diagram, superimposed on the satellite track plot, the mission planner can evaluate the best GPS observation window based, for example, on Geodetic Dilution of Precision(GDOP). Preliminary tests have demonstrated that this photogrammetric method of generating obstruction diagrams can favourably replace the usual site reconnaissance *(Santerre & Boulianne, 1995)*.

5-Applications

The preceding two packages present interesting examples of the field extension made possible by softcopy photogrammetry and which corresponded to a basic orientation of the DVP development. In forestry, DVP applications have been reported before the introduction of DVP-FOR. *Klaver and Walker(1992)*, have mentioned its use for digitizing of tree stand contours. The module DVP-MONO, used in conjunction with a DTM file, now makes possible the same operation, in a simple and efficient way, directly from a paper photograph. Other applications have been mentioned in different publications, for instance: archeology and close-range photogrammetry applications *(Boulianne et al.,1991)*; 3D spatial analysis *(Gagnon et al.,1993b)*, geological and environmental applications *(Blais et al.,1993,1994)*. *Polnar et al.(1992)* have reported the successful use of the DVP to obtain 3D quantification of stereopairs of images (lung cells under a 5000x magnification) taken with a Scanning Electron Microscope. The authors mention that attempts at getting the same information via non-photogrammetric methods had proven unsuccessful.

Not surprisingly, however, most current applications of the DVP system remain inside the basic mapping and map updating industry itself. Of the few hundred DVP copies that have been distributed, to date, in all parts of the world(in 45 countries covering the 5 continents), less than 10% are to be found in organizations that already had a photogrammetry operation. This a clear indication of an extension of the traditional photogrammetry practitioner base. It is also an indication of the usefulness of the new accessibility. A new category of photogrammetry practitioners have seized the opportunity offered by the DVP and entered the mapping industry market. Such an extension comes at an appropriate time: in recent years, many authors (e.g. the list presented in *Estes and Mooneyhan,1994)*, reporting on the worldwide mapping problems, have mentioned the impossibility of dealing properly with them, if only traditional photogrammetric means and the traditional practitioner base were considered.

Also, because more than 15% of DVP users are surveyors or survey engineers, it is reasonable to expect that the technology will come to be used for survey operations as naturally as photogrammetry is now used for mapping. With the digitizing, topographic and vector superimposition functions of the system, topographic operations can be directly performed in the stereomodel: measurements of angles, distances, areas, etc. The operations lead to DVP applications for cadastral work, site and construction planning, simulations, etc.

6. Conclusion

From an objective–oriented standpoint, the dynamism of the DVP development, as evidenced by the improvements, additions and applications presented above, has been and continues to be prompted by the importance of the mapping needs. And what has been achieved constitutes a clear testimony that softcopy photogrammetry has now successfully paved its way out of its original research and academic environment and started its contribution with respect to these needs. From a technical standpoint, that dynamism has been and continues to be directly related to the dynamism of the microcomputer technology. Any processor, bus, memory, videocard, cache, disk, frequency, or operating system, etc. improvement means a direct or possible improvement of DVP operation and performance. For instance, snap search time and screen refreshing time, which could be found too slow, at first, for some applications, have now become completely adequate with the upgraded hardware components. Hardware component improvements also open the door to the development of new possibilities (e.g., a new feature, a new module or a new package), oriented, as always, at making the system more efficient and more user– friendly on its low–cost and standard platform. On the subject of low–cost and standard hardware components, *Heipke(1995)* states: *" sooner or later, it will be possible to build a DPS with only commercial off–the–shelf parts."* It is interesting to note that what is seen as part of the normal evolution of softcopy photogrammetry has been a reality with the DVP from the start.

It is also important to note, finally, that the extension of the user base, as made possible with the DVP or similar systems, conveys educational implications. With the DVP, difficulties related to access, cost and operation have been greatly reduced but difficulties related to the good practice of photogrammetry remain: no degree of software sophistication and user–friendliness can replace a sound knowledge of photogrammetry. Consequently, an appropriate educational response is needed in order to match the dynamism and potential of the technological developments, of which the DVP is a good example, and to optimize the benefits potential related to these developments. Assuming that the necessary educational response is provided, systems of the DVP type will have their full impact and certainly open a new world in the practice of photogrammetry.

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Jacques has been a member of the *Ordre des Arpenteurs–Géomètres du Québec* since 1968 For more than 20 years, he was a major associate in *Emond et Coulombe & Ass.*, a survey engineering firm. He is now president and general manager of DVP Geomatics Systems Inc., a firm that he founded for the user– interface development,promotion and distribution of the DVP family of products.He is also president and general manager of EMCO Inc., a firm involved in data conversion and maintenance. EMCO is the permanent beta site for all DVP products.

Paul–André Gagnon became a member of the *Ordre des Arpenteurs–Géomètres du Québec* in 1963 and, in 1968, received a Ph.D. in Applied Sciences from Laval University, where he became full professor in 1974. His research activities have been mainly oriented at photogrammetry and photogrammetry applications. Results of his research activities have been presented in a number of articles and technical reports. From 1975 to 1979, he was vice president and general manager of Aéro–Photo Inc., Québec. Between 1979 and 1984, he was research associate dean at the *Faculté de foresterie et Géomatique* of Laval, where he is currently involved in teaching and also, in research activities at the *Laboratoire de photogrammétrie numérique,* where the DVP concept has originated.

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Customer Orientation of the Leica Digital Photogrammetric Systems by Helava

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Summary
Leica digital photogrammetric systems by Helava are based on the DSW200 Digital Scanning Workstation and DPW670/770 Digital Photogrammetric Workstations. These systems continue to develop, in terms of both host computer hardware and software functionality. The driving force behind the development directions is the satisfying of ever increasing customer demands, pari passu with the need to survive by staying ahead of the competition. The result is considerable flexibility in conjunction with rich software packages.

1. Introduction

The relationship between Leica and Helava began in 1991 and has enabled Leica to distribute digital photogrammetric systems of great pedigree (Miller, Helava and Devenecia., 1992). The development of these systems has been extensively recorded, for example by Miller, Thiede and Walker (1992) and Miller and Walker (1995). At present the systems are centred on the DSW200 Digital Scanning Workstation, in which film imagery is converted into digital form, and the DPW670/770 Digital Photogrammetric Workstations. An extensive range of software has become available and the SOCET SET® suite for the DPWs is especially well known. This paper summarises the current (mid 1996) state of development and goes on to discern some trends amongst the expanding customer base with respect to both applications and requirements.

2. DSW200 Digital Scanning Workstation

The DSW200 (figure 1) was launched in the autumn of 1994 and almost 50 are in use worldwide. Based on a SPARCstation host computer, continuous xenon light source transmitting via liquid pipe optic, integrating sphere and a simple, unfolded optical train with a single lens to a Kodak MEGAPLUS digital camera, it represented a leap in performance over its PC-based DSW100 predecessor. The camera is a state of the art square CCD array model, with 2029 x 2044 pixels of size 9 µm and termed "full fill factor", i.e. the great majority of the area of each pixel is light sensitive, giving high radiometric performance. Both camera and lens can be moved to give a pixel size on the image in the range 5-16 µm. The geometric performance is similar to an analytical plotter, with root mean square errors of less than 2 µm on each axis. The unit can output both 8 and 10 bit data over a broad density range. Colour filters are located in a software controlled wheel in front of the light source; these components, together with the power supply and electronic controller are located in a box remote from the xy stage, to isolate the latter from heat or vibration.

Figure 1. DSW200 Digital Scanning Workstation

Four models are on offer at present and are differentiated in terms of the digital camera and the host computer (table 1). All models have Sun host computers and systems are typically supplied with 128 MB RAM, 8.5 GB hard disk capacity and 7-14 GB 8 mm tape cartridge drive.

Model	Kodak MEGAPLUS camera	Sun host computer
DSW200	4.2i	SPARCstation 20SX/71
DSW200	4.2i	SPARCstation 20SX/712MP
DSW200	4.2i	Ultra 1 Creator Model 170E
DSW200e	1.6i	SPARCstation 5 Model 110 S24

Table 1. DSW200 models

Performance has always been impressive and continues to improve. With the Ultra host, for example, a black and white aerial photograph can be scanned in about four minutes at 12.5 µm; JPEG compression in software takes around eight minutes.

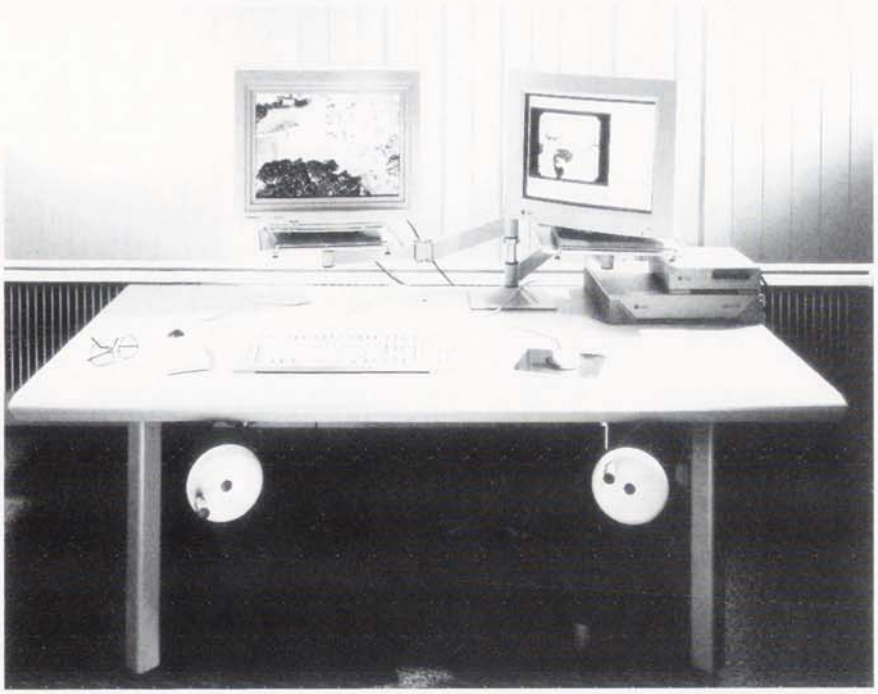

Figure 2. DPW770 on Sun SPARCstation 20 with NuVision viewing system

The software develops incrementally and recent developments have included automated interior orientation, upgraded JPEG software and tiled TIFF format. The routines for automated calibration have been extended to include radiometric calibration with a "sandwich" of stage plate, homogeneous grey tone film sample and cover plate: the results from this make it almost impossible to spot joins between the camera patches, even in dark, fairly uniform parts of the image such as water areas. The software suite was ported to Sun's Solaris 2.5 at the beginning of 1996. In summary, the DSW200 works well, but care and experience are still the keys to successful scanning of colour or negative materials.

3. DPW670/770 Digital Photogrammetric Workstations

The range of systems which has evolved over the last four or five years is continued and the workstations benefit from frequent hardware improvements introduced by the workstation vendors. The DPW670 is a monoscopic workstation with the option of the Leica DVP Viewer for occasional stereoscopic observation in split screen mode. The DPW770 is a dual screen, fully stereoscopic workstation with viewing by means of either the NuVision passive polarised system or the Stereographics CrystalEyes® approach with active LCD shutter eyewear (figure 2). Currently, a broad range of hosts is offered. The DPW670 is available with many models of Sun SPARCstation, Sun Ultra, Silicon Graphics (SGI) Indy and SGI Indigo2. The DPW770 is slightly more hardware dependent owing to the stereoscopic facility and is offered on: Sun SPARCstation 20/71, 20/712MP, 5 Model 110; Sun Ultra 1 Creator 3D Model 170E; SGI dual head Indy; and SGI dual head Indigo2 with two XL cards. At the time of writing, work on SGI Indigo2 with High or Solid Impact graphics is well advanced. The workstations are typically offered with 64 MB RAM (128 MB on DPW770 on Sun Ultra), 6.4 MB hard disk capacity and 7-14 GB 8 mm tape cartridge drive. To a certain extent, the differences between these variants are unimportant, in the sense that the software functionality is rather similar in all cases, but many customers strongly prefer one host or another and it is our policy to meet these demands wherever practical. Naturally, the higher end workstations offer more performance: the dual processor SPARCstation, the Ultra and the SGI machines offer faster computation, for example for big DTMs, and the high performance Ultra and SGI graphics enable fairly smooth roaming (all DPWs have fixed cursor moving image and fixed image moving cursor as standard). The Sun Ultra 1 Creator 3D (like the Creator on the DSW200) offers fast and wide SCSI-2 and fast Ethernet (100-BaseT) as standard, whereas the SGI IRIX operating system can treat two physical SCSI-2 disks as a single logical disk, resulting in performance rather similar to fast and wide SCSI-2. In short, hardware performance continues to improve and amaze.

Several customers have opted to purchase economical dual configurations, in which the DSW200 have shared the same SPARCstation 20 host as the DPW770. As digital business has expanded, however, most of them have purchased a second host and separated out the two components.

4. Software for the DPW670/770

4.1 SOCET SET®

The keystone of the digital photogrammetric software, SOCET SET (acronym for the transatlanticism <u>So</u>ftcopy <u>E</u>xpoloitation <u>T</u>ools), dates back six years and has been extensively documented elsewhere. Suffice it here to summarise recent changes. The CORE module, which incorporates all the basic functionality, has been enhanced with a Model Manager, in which stereomodels may be defined in terms of their constituent images and rapid switching between them performed, rather like a digital equivalent of BC1S or DSR15-18 analytical plotters, but faster and with more than two models. The modules to import and handle satellite imagery are being increased, with a new one for IRS-1C in preparation.

One of the biggest innovations is HATS (Helava Automated Triangulation System: Miller and Walker, 1996), which performs automated triangulation by area based image matching for automated measurement of control and tie points. Full details are beyond the scope of this paper, but it is important to emphasise that times of the order of ten minutes per image have been achieved: these have to be compared to the sum of the preparation, point marking and transfer, observation, bundle adjustment and reobservation phases of analytical triangulation. At present the module is being extended to incorporate customers' GPS data. Leica has developed a utility module for transfer of orientation data between the DPWs and a number of analytical plotters.

The TERRAIN module for extraction of DTMs by image matching has developed incrementally, with algorithmic enhancements to improve matching in difficult areas and some new interactive editing tools. An early implementation of Iterative Ortho Refinement (Norvelle, 1994) has been added too. The ORTHO module has been extended with bicubic resampling and with True Ortho, whereby compensation is rigorously applied for building lean. Occluded areas are filled in from adjacent images. Further work is required in some areas, for example multilevel highway intersections.

The long established layer mosaicking has been enhanced with the addition of complementary quick and automated mosaicking. Quick mosaicking may more accurately be described as a multiple input, single output orthophoto, with automated image balancing and feathering, but with the option of user defined seamlines, for example to avoid the aesthetically unacceptable situation where an automated seamline goes through a building. Automated mosaicking is a commercial version of software developed for military purposes, whereby the whole process from raw imagery to final mosaic, via triangulation and DTM extraction, is completely autonomous. In some cases this works well with satellite data, but with aerial photography the products are unlikely to meet normal mapping standards.

The IMAGE-MAP facility has been extended to include PostScript output, specially refined such that vector and text data may be incorporated in the output file at higher resolution than the image - usually digital orthophoto - component, in order to exploit the advantages of modern laser raster plotters to the full.

Importantly, the F-GIS module for feature extraction now includes three semi-automated feature extraction (SAFE) tools, for measuring buildings, delineating lines and forming regions such as lakes. In all cases the goal is to develop approximate measurements by the human operator into accurate delineations by means of image processing. The evidence so far is that substantial increases in productivity and reductions in fatigue may be routinely expected.

A new module called CLOSE-R has been added, to incorporate the same close range functionality that is available on Leica analytical plotters (Hinsken *et al.*, 1992). The special advantage of digital photogrammetry in this case is that data from digital cameras may be straightforwardly imported.

4.2 Applications Modules

For feature extraction, KLT's ATLAS and Leica's PRO600 interface to MicroStation are the premier offerings. Both of these packages are continuously enhanced. PRO600 has recently been extended with the option of the TerraModeler module from Terrasolid Oy of Helsinki for TIN creation and manipulation, paralleling the powerful TIN functionality already offered as an additional module for ATLAS users. Helava's F-GIS feature extraction module, popular in the military community, is also available. KORK users have been weaned on to other packages since their feature extraction software was sold to Vision International, but Zeiss CADMAP and DAT/EM DGN/CAPTURE are available. GIS users have the options of

Clemessy GeoCity or Unisys System 9 on-line, but further feature extraction and GIS packages are continuing to be added.

5. Customers and their Changing Requirements

The customer base has expanded dramatically despite the most aggressive competition. A rich variety of private mapping companies, national mapping organisations, transport departments and educational and research institutions bring a host of challenges. Today's customers are knowledgeable and demanding. Quite rightly they expect digital photogrammetric products not only to follow rather closely behind computer manufacturers' developments but also to be tuned to their particular requirements. One well known customer, the Ordnance Survey of Ireland, for example, has required quite complex networking configurations including efficient connection to existing systems and has been the driving force behind the recent development of software for quality control of orthophotos (Kirwan, 1996). Several national map projections and mathematical models for space imagery have been added in response to customer requirements.

Customers' applications increase in number. As one would expect, the most common are DTM extraction, orthophotos and mosaics, with feature extraction *per se* often left for analytical and analogue workstations, though this is changing. Now close range photogrammetry (Connelly and Byrne, 1995), change detection, for example to measure forest growth or monitor urban development, models for optimum placement of telecommunications hardware and measurement of snow volumes are all carried out routinely. One customer has combined conventional image maps with true orthos and perspective scenes for planning purposes in the exciting case of the UK's rail link to the Channel Tunnel (Simmons, 1996). Others like to interface their own software modules using SOCET SET's development tool kit (for example, Kölbl and Walker (1993)). It is interesting too that the military business of GDE Systems, Inc., Helava's parent company, goes from strength to strength, but COTS hardware and SOCET SET software are increasingly providing the environment for the classified applications to run successfully and economically. These special customers are just as demanding on the scanners as the several commercial scanning bureaux which work their DSW200s shift after shift! In short, the adoption of digital photogrammetry has proceeded apace, but in no way do customers view the products as "off the shelf": each system is different and many incorporate special features to meet individual requirements.

6. The future

The pace of change is already breathtaking, with hardware and software developments emerging every few days or weeks. In the near future, we anticipate accommodation of continuing hardware improvements such as the SGI R5000 and R10000 processors and the 4K x 4K Kodak cameras. Customers' demands for roll film scanning and PC versions of SOCET SET are being treated very seriously. More attention must be focussed on ergonomics and automation, especially for feature extraction, where the case for changing from analytical plotters is not yet proven; semi-automated measurement of ground control points is but one innovation which will be necessary. Some experts predict that photogrammetric and remote sensing requirements will coalesce in a single workstation: for us this means the addition of the sophisticated image processing functions typically found in remote sensing packages. Perhaps most importantly, we are grappling with the challenge of operational, useful software for project management and workflow optimisation. These goals will be met in due course, but the day to day tuning and customising in response to customers' requests has to be superimposed on the medium term development plan.

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Intergraph Integrated Digital Photogrammetry System

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Abstract

Digital photogrammetry brings about some fundamental changes in operations for photogrammetric workflows. The first and most obvious one is the requirement for digital images; typically this is accomplished by scanning film transparencies of aerial photographs. Secondly, a digital stereoplotter workstation is now a powerful computer that is specially configured to perform rigorous photogrammetric tasks. To integrate these two changes into a productive system, two more changes have to be considered. They are the fundamental changes inherent in a softcopy system, and the photogrammetric workflows, which are aerial triangulation, feature and elevation collection, and orthophoto production.

In this paper, the concept of the Intergraph digital photogrammetry production system is described. Major hardware and software configurations of such a system are given. Brief descriptions of digital photogrammetry applications, such as digital mensuration and triangulation, three-dimensional feature and DTM collection, and orthophoto creation, are provided. Multi-sensor triangulation and close-range photogrammetry applications are also briefly discussed. Finally, some general concluding remarks are provided.

1. Introduction

Over the past 70 years photogrammetry instruments have undergone a tremendous evolution from analog, to analytic, to digital or "softcopy" systems. The impetus for this evolution has been the advancement of computer technologies.

An integrated digital photogrammetry system is defined as hardware and software configurations that produce photogrammetric products from digital imagery using manual and automatic techniques. The output for such systems may include three-dimensional object point coordinates, restructured surfaces, extracted features, and orthophotos. While the principles of photogrammetry have not changed, the tools have. Creating a digital photogrammetry production system requires thoughtful integration of the latest technologies with respect to traditional photogrammetric workflows.

Scanning is a very critical step in the digital photogrammetry environment. Errors that are introduced at the scanning stage remain throughout the photogrammetric process. It is vital to photogrammetric production to preserve the precision of both the radiometry and geometry of the aerial photograph. Scanning in an integrated digital production environment must be timely in addition to being accurate. A scanned photo that is ready for production needs to be in a useful format, which may include tiling, overviews, and compression. Putting the file into a useful format can be done either at scan time or as a batch process after the scanning. Several factors, such as the number of photos in a job, help determine whether the processing is done at scan time or in batch.

Digital stereoplotter workstations, powerful computers configured to do the work of a stereoplotter, are very important components of the digital photogrammetry workflow. This is where the execution of photogrammetric applications takes place. The digital stereoplotter workstation itself is the result of an integration of the digital photogrammetry requirements for the host computer. These requirements include a high-quality stereo display, the ability to handle large images efficiently, and a productive ergonomic design. A high-quality stereo display is important both for comfortable stereo viewing and the accurate identification of image objects. The efficient handling of large images must go beyond the obvious storage and retrieval devices, i.e., large disk drives and 8 mm tapes, and the digital stereoplotter workstation must be powerful enough to perform smooth stereo roam. Stereo roam allows the operator to move the stereo model behind the measuring mark, similar to moving the plates or stages "behind" the floating mark on analog or analytical stereoplotters, and it enables the operator to follow features such as rivers and roads across the extents of a stereo model. An ergonomic design must not be overlooked; even digital photogrammetry production still requires human beings to perform the necessary tasks efficiently.

There are two major differences between a digital stereoplotter workstation and an analytical stereoplotter. The first and perhaps the most significant is input data. Most problems arise due to the extremely large size of the digital images. An aerial photograph of 230 x 230 millimeters that is scanned at a 30-micrometer resolution requires about 60 megabytes of storage. This alone can almost cause the photogrammetric workflow to grind to a halt if not handled properly. The most efficient way to handle the large image files is through smart file formats and image compression techniques. Smart file formats employ techniques such as image tiling and image pyramids and allow for efficient memory management and more efficient processing. Image pyramids are used for to display imagery at all zoom levels very quickly and are also used in automatic measurement and image matching algorithms.

The second fundamental change brought on by the digital photogrammetry system is a potential for automated measurement and image matching that simply did not exist in the analytical stereoplotter environment. The automatic measurement and image matching techniques are the great value added components that the new digital technologies bring to photogrammetry.

2. Hardware Configuration

The Intergraph integrated digital photogrammetry system consists of the following components:

- InterMap 6887 ImageStation
- PhotoScan

2.1 InterMap 6887 ImageStation

The InterMap 6887 ImageStation digital stereoplotter (IMD) is an analytical stereoplotter that integrates the power of the Intergraph IP6887 ImageStation with 3-D stereo viewing. It is designed for users needing photogrammetric functionality for map compilation and revision, engineering mapping and revision, orthophoto production, transportation alignment cross-section collection, digital terrain collection, GIS input and revision, and close-range applications.

IMD provides stereo graphics on a 24-bit true color 27-inch monitor. A JPEG compression/decompression processor allows the use of high-resolution scanned imagery while minimizing the file/storage size of the image. An infrared emitter and liquid crystal glasses provide a high-resolution 3-D image. IMD is also offered with the VI-50 image computer and 64 megabytes of onboard ECC memory as a standard configuration. An ergonomically designed work/digitizer table (34 x 22 inch sensitized area), which includes a 10-button two-handed cursor and a cantilevered monitor table, complete the IMD configuration (Figure 1).

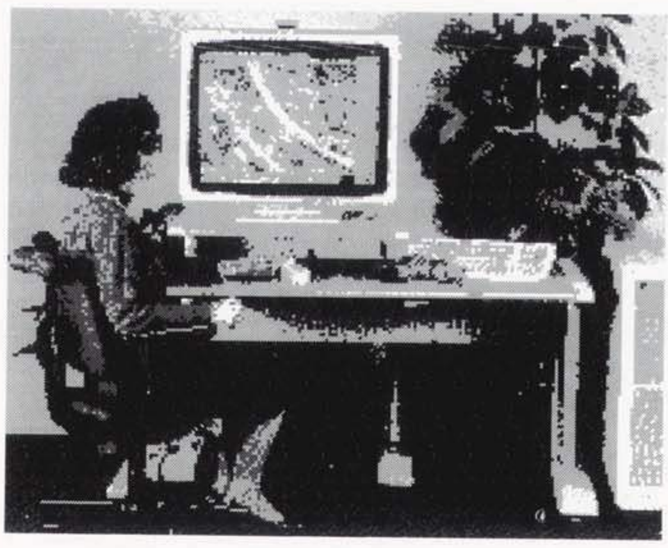

Figure 1. InterMap 6887 ImageStation

2.1.1 Hand-Held Controller

The hand-held controller (HHC) is a pointing device used on the digitizing surface to move the cursor to select input, and to perform high precision 3-D mensuration. The HHC and the digitizing surface provide an absolute coordinate system where every point on the digitizing surface is mapped to a point on the screen.

2.1.2 Crystal Eyes

The ImageStation digital stereoplotter integrates a stereo viewing system that uses an infrared emitter and liquid crystal glasses. The left image of a stereo pair is displayed on the odd lines of the screen; the right image is displayed on the even lines. These rows are alternated so that first one image is displayed, then the other. The images are controlled by the Crystal Eyes system, consisting of a remote signal emitter synchronized with the 120 Hertz image flicker rate and a pair of glasses that receive the signal. When each lens receives the proper signal, it becomes either transparent or opaque, depending on which image is being displayed. The result is that you see the right image with your right eye and the left image with your left eye so that the image pair appears as a single, continuously displayed stereo scene.

2.1.3 VI-50

The VI-50 is the ImageStation's raster processor which operates at about 300 MOPS (million operations per second). With the VI-50, the ImageStation can do real-time stereo roaming and digitizing with true color images and vectors. The VI-50 is also used for resampling the raw images into epipolar geometry for stereo viewing/digitizing and for resampling the raw images into orthophotos.

Since the VI-50 uses dual roam buffers, the ImageStation can roam throughout an entire stereo model regardless of size. As the operator moves around the stereo model, the roam buffers get the needed image tiles from the disk. This eliminates the need to constantly reload sections of the stereo model into available memory for roaming or for putting excessive amounts of memory on the workstation. Another important feature of the VI-50's roam buffers is its smoothness.

2.1.4 JPEG Compression/Decompression

Intergraph has incorporated the Joint Photographic Experts Group (JPEG) algorithm into a
JPEG image compression/decompression hardware board. The JPEG compression algorithm utilizes a Quantization/Quality factor, or Q-factor. The Q-factor is variable between 1 and 300, with a smaller value meaning less compression. Typically, if a low Q-factor of 25 is used, an image compression of 3-4 times is achieved (depending on image texture) without any noticeable

change in image quality or detail on grey values. For example, an uncompressed black-and-white image scanned at a 30-microns (um) has a file size of about 60 MB. This means that a single 2.1 GB internal hard disk will be able to hold 35 black-and-white aerial photographs at 30 micron resolution. With JPEG compression, the number of images that can be stored increases to 105.

When the imagery is needed for viewing or other subsequent processing, it first moves in real time from the disk through the JPEG board to get decompressed on-the-fly before being displayed on the monitor. So the imagery is always compressed on the disk and decompressed on the screen or when being processed. Since this is done with hardware on-the-fly, the decompression to the screen is completely transparent to the operator.

Another plus for JPEG compressed imagery is that since the files are smaller, they transfer over the network and backup to tape faster. Even application software (like orthophoto) processes compressed imagery faster than decompressed imagery.

2.2 PhotoScan

PhotoScan is a high-resolution, radiometrically and geometrically precise, flatbed scanning system and was designed specifically to address the requirements for high-end photogrammetry and image processing film conversion. The PhotoScan converts photographic information from black-and-white or color and from positive or negative film sheets into continuos-tone digital raster image data at a rate of up to 2 million pixels per second (Figure 2). Typical 9"x9" aerial diapositives can be scanned at 15 um (microns) resolution (240 million pixels) in as little as 5 minutes after less than 2 minutes loading and setup time! The PhotoScan system is based on a precision opto-mechanical digitizer module which is manufactured for Intergraph by Carl Zeiss - Germany. This unit is interconnected via a specialized Camera and Electronics Interface to an Intergraph 6000 Series workstation with a 19-inch or a 27-inch display monitor.

The digitizer is equipped with a fully-gain/bias-compensated, high-quality camera system which uses a linear Charge Coupled Device (CCD) sensor with 2048 elements for high-quality, high-speed digitizing. PhotoScan fixed optics produces a 7.5 um pixel size for the camera system, which is digitized to a minimum of 10 bits prior to compensation and digital aggregation to the user-specified resolution. Resolution options include the basic 7.5 um pixel size as well as 15 um, 22.5 um, 30 um, 60 um, and 120 um for the user to select from. Generally, 15 um, 22.5 um, or 30 um is the common resolution for production work, and 60 um or 120 um is the common resolution for quick 'overview' and/or setup purposes.

Figure 2. PhotoScan PS1 System

PhotoScan also has a unique "interior orientation" feature which allows for precision interactive measurements of fiducials or reseau points prior to the digital image collection. These measurements can be stored into the associated image 'header' file for defining the scan coordinate system used for collecting the digital photo, and can also be used to control the physical scan orientation to align precisely with specified photo coordinate system.

3 Software Configuration

The Intergraph Integrated digital photogrammetry system software is designed for a complete end-to-end digital workflow. This workflow may be divided into separate "visual database creation" and "visual database exploitation" operations (see Section 4.2). The visual database creation deals with photo scanning, image mensuration and adjustment (orientations and/or bundle), and epipolar image generation. The visual database exploitation deals with 3-D feature /DTM collection, CAD model generation, and orthophoto creation (Figure 3).

In general, the major digital photogrammetry workflows are as follows:

- Mensuration and triangulation
- 3-D Feature and DTM extraction
- Orthophoto Generation

3.1 Digital Mensuration and Triangulation

ImageStation Digital Mensuration (ISDM) provides a multi-image (up to six images at once), multi-sensor, point transfer and measurement environment for a photogrammetric triangulation workflow. Image points can be measured in single-cursor mode or multi-cursor (stereo) mode. The image point coordinates generated by ISDM can be used in PhotoT (included bundle adjustment) module or can be formatted for input into one of the Intergraph supported third- party triangulation packages by ImageStation Photogrammetric Manager (ISPM). This process results in a photogrammetric solution for the subsequent stereo resampling process.

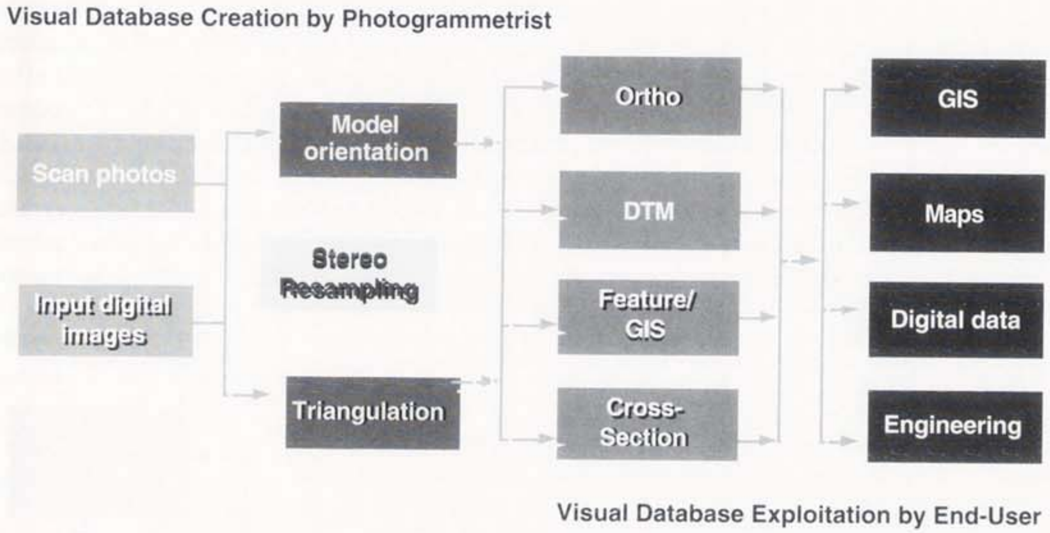

Figure 3. Digital Photogrammetry Workflow

The high degree of flexibility built into the user interface allows a highly automated mensuration procedure. A flexible window-based image display of multiple images provides the efficient transfer and measurement of points in multi-overlap regions. The use of auto-correlation and on-line integrity checks improves accuracy, increases productivity, and increases reliability. The accessibility of the image enhancement and image manipulation functions greatly assists the operator in performing the mensuration task.

The primary components of the ISDM software are project selection, interior orientation, single photo resection, relative orientation, absolute orientation, and bundle adjustment.

Interior Orientation: The Interior Orientation (IO) process determines the relationship between the calibrated fiducial (reseau) coordinates and the image pixel coordinates. The basic workflow is to select a fiducial (reseau) in the Overview window and to follow it through the Full Resolution and Detail windows. The cursor moves from window to window, narrowing into on the selected point. A mathematical transformation (Rigid Body, Conformal, Affine, Projective) is then computed using the calibrated fiducial (reseau) coordinates and the corresponding pixel coordinates. The user can review the IO results and remeasure, delete, withhold, or reinstate any fiducial measurement at anytime during IO, if necessary.

After the first photo is measured, all subsequent photos in the strip can be measured automatically. Using this process, entire strips of photos can have an interior orientation performed extremely quickly and easily. This process could save a great deal of time for large strips of photography.

Relative Orientation: Relative Orientation (RO) determines the relationship between two images. After several points are measured to establish an initial relationship between images, an auto-measurement utility in the mensuration software performs image correlation between stereo pairs to assist in the location of conjugate points. Control and check points can be measured as parallax points; they are then carried through to the Absolute Orientation (AO) process, where they revert to control/check points. A mathematical transformation is then computed using the coordinates for the same point in the left and right images. The results are presented in the form of image residuals, y-parallax, sum of redundancy, and other statistics. The RO points can be deleted, remeasured, withheld, or reinstated, if necessary.

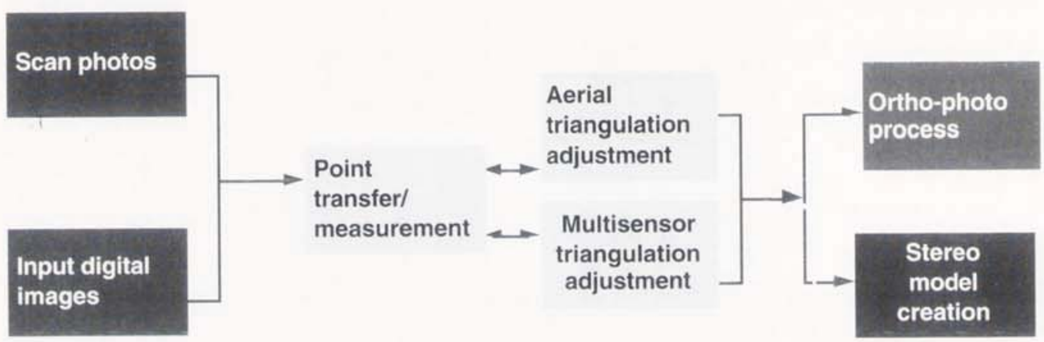

Figure 4. Digital Mensuration/Triangulation Workflow

Absolute Orientation: Absolute Orientation (AO) determines the relationship between model coordinates and the corresponding ground coordinates. In AO, the user can measure control points (full, planimetry, or vertical) or check points. During AO, a mathematical transformation is computed using the given coordinates and the observed model coordinates. The AO adjustment results are displayed after the minimum number of points has been read. The AO points can be deleted, remeasured, withheld, or reinstated, if necessary.

Single Photo Resection (SPR): SPR is a single-image orientation that allows the user to determine the relationship between image coordinate and corresponding ground coordinate systems. Image exterior orientation parameters can be used to create an orthophoto or another perspective view.

PhotoTriangulation (PhotoT): Photo triangulation provides the user with an interactive interface to a bundle adjustment program and other tools facilitating the photogrammetry adjustment process. PhotoT is used to compute camera positions and attitudes for all imagery and for 3-D object coordinates for all transferred (tie/pass/parallax/control/check) points.

PhotoT uses the standard least squares bundle adjustment procedure, incorporating a priori information for exterior orientation parameters. The other tools provided in PhotoT are useful for setting up adjustment parameters such as blunder detection and variance-covariance computation, selecting photos/models, quality control analysis for (IO, RO, AO, Bundle), Draw Footprints, Draw 3-D points, and Bulk Processing. The densification process is the last step in the photo triangulation process. During this process all transferred points are densified to control points.

3.1.2 Epipolar Resampling

After the elements of exterior orientation have been calculated for each photo, either from an aerial triangulation adjustment program or directly from absolute orientation, the images will then be resampled into the epipolar format.

Resampling to the epipolar format, a batch mode operation, involves a re-arrangement of the pixels in each digital photo of a stereo model in such a way as to remove all the y parallax (i.e., along the epipolar lines). Epipolar resampling also removes the effects of tilt, tip, and swing from the aircraft and incorporates any corrections the operator may have applied such as earth curvature, atmospheric refraction, and lens distortion. This is the preferred viewing mode in digital photogrammetry, significantly reducing eye strain and therefore operator fatigue. The resulting images will then be ready for stereo 3-D extraction.

3.2 3-D Feature and DTM Extraction

After resampling into epipolar geometry, each stereo model is ready for stereo viewing and digitizing. This step uses ImageStation Stereo Display (ISSD), MicroStation Feature Collection (MSFC), ImageStation DTM Collection (ISDC), and ImageStation Match-T (ISMT) modules.

3.2.1 ImageStation Stereo Display

ImageStation Stereo Display (ISSD) is a stereo raster image display and manipulation product. It is used to display and manipulate stereo imagery with photogrammetrically accurate 3-D cursor tracking and stereo vector superimposition using IMD stereoplotter workstation. With this product, it is possible to display monochoromatic images, color index images, and color composite images. ISSD uses layer capabilities to load and process multiple image files.

ISSD uses image interlace technology to display stereo imagery by allocating alternate rows of pixels to each image. The result of this interlacing and switching is that you see only the right image with your right eye and only the left image with your left eye. This gives the user extremely comfortable, flicker free stereo viewing.

Main ISSD Features

- Stereo display images in fixed window with moving cursor
- Stereo roam when using ImageStation with VI-50 image computer
- Real-time image decompression/compression using JPEG hardware
- Image overviews (image pyramids) for fast image displays
- Image zoom and window commands allow control of image display scale
- Balancing of image contrast and brightness for stereo and split screen displays
- Histogram matching for image balancing
- Vertical Index to check the operator bias
- Image Index Review (IIR) for graphically picking imagery

3.2.2 Map Feature Collection

MicroStation Feature Collection (MSFC) provides a low-cost, easy-to-use, map feature digitizing system for use with stereo aerial, SPOT, and other satellite imagery. MSFC provides an efficient map feature digitizing system that extends MicroStation capabilities. It furnishes numerous commands to collect and edit feature data. MSFC utilizes screen-based, icon-driven menus to provide a user interface designed for map production. Efficiency is enhanced by setting the feature's graphic characteristics and activating a digitizing command upon selection of a feature. A feature-based table is utilized, allowing the user to define a series of map symbologies and manage them on a job-by-job basis. A default table is delivered with the software. It can also bulk load data directly into Intergraph Modular GIS Environment (MGE) software (Figure 5).

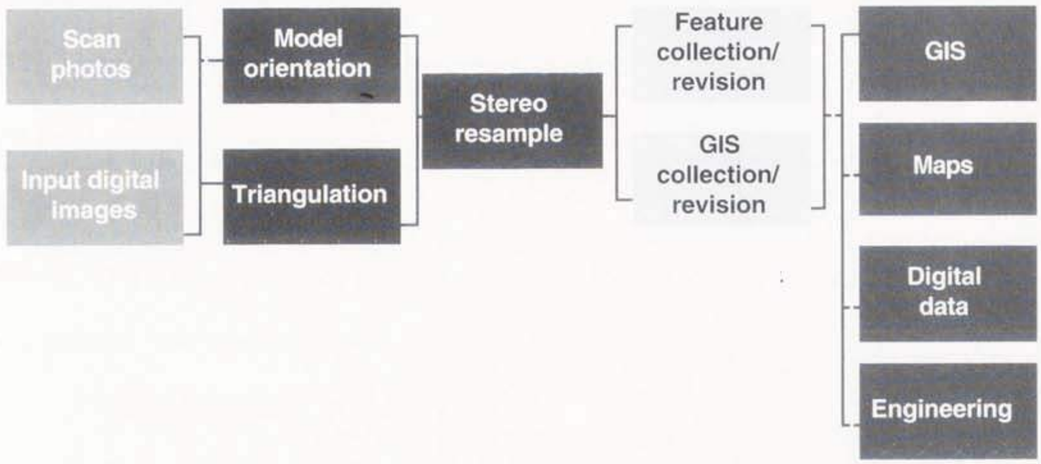

Figure 5. 3-D Map Feature Collection/Revision Workflow

3.2.3 DTM Collection

ISDC provides an interactive method for stereo compilation of digital terrain models and ISMT (third-party product developed by Inpho, Germany) provides a method for automatic generation of elevation data via batch processing (Figure 6).

ISDC relies on MSFC for setting up the ISDC feature definitions such as DTM points and breaklines. ISDC runs concurrently with MSFC and provides a full feature base to allow user definable geomorphic terrain features.

ISDC's collected elevation data can be used by Intergraph DTM products such as MSM, InRoads, or InSurv to create contours or perform a variety of modeling earthwork and engineering functions. This data can also be used in MGE products for digital land base creation and revision.

Main ISDC Features

- User definable collection areas can range in size from an entire stereo model to any smaller portion of the stereo model defined by the operator
- User definable geomorphic features, such as breaklines, ridge lines, drain lines, vertical faults, and elevation points, can be defined in a feature table to any level, color, weight, and line style
- Planimetric features, such as drainage, retaining walls, and road edges, can be brought into ISDC and used as geomorphic features
- Handles arcs, curves, and line fillets as breaklines
- DTM collection from SPOT stereo imagery
- Different modes of semi automatic DTM collection utilizing Cursor-On-Surface (COS) module

- Full model modification and manipulation, fence editing, as well as feature tag and attribute editing
- Obscure area definition allows the operator to select areas where no DTM collection or contour generation is desired
- Adverse area definition excludes zones as defined buildings or areas of tree canopy from being correlated by ISMT
- On-line triangle and contour generation allows the operator to view contours over the collected area while still in the model
- Dynamic editing of triangles and contours shows operator the effect of edits in real-time
- Overlay ISMT batch DTM extraction on the stereo model for editing and detection of trouble areas
- Queue processor to drive operator to suspect points detected by ISMT Import and export various DTM file types into ISDC

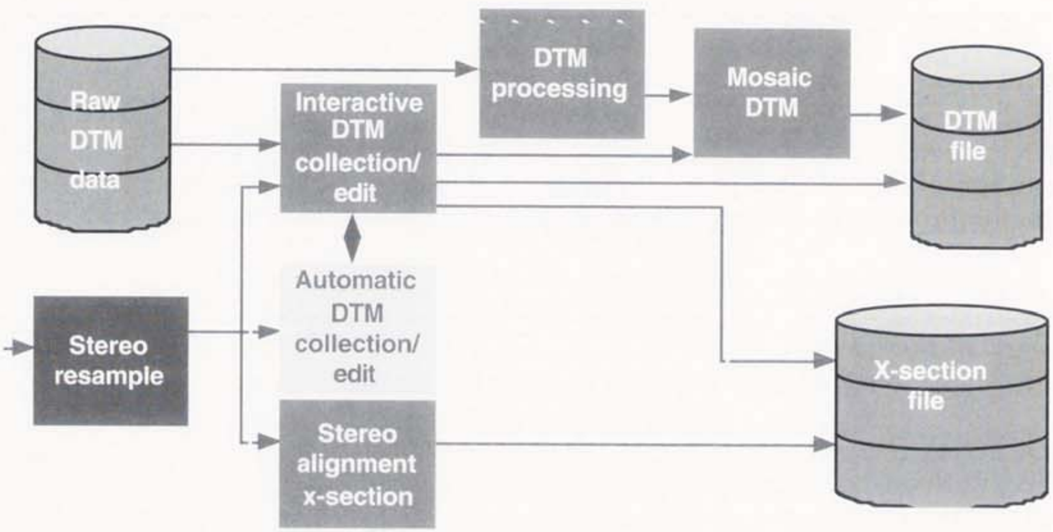

Figure 6. Elevation Collection/Processing Workflow

ISMT extracts DTM points from digital aerial and SPOT stereo pair images. ISMT has a high overall accuracy because it generates a large number of DTM points. The DTM generation is carried out stepwise by going through a pyramidal data structure. The process on each pyramid level can be divided into the preliminary matching of conjugate image points, a 3-D intersection from these conjugate points into object space, and a robust DTM modeling with bilinear finite elements. The conjugate image parts for the matching are divided by the re-projection of single meshes of an initial DTM into the image.

Main ISMT Features

- Raster file structure
- Generate DTM points in a model, object, or user-defined coordinate system
- Generate DTM points from black-and-white and color (one band can be defined) imagery
- SPOT Image DTM capture using Rational Functions
- Batch processing
- Batch output of ISMT generated points into design file
- Suppression of grid points near breaklines
- Separate class definitions and symbologies for points of different statistical qualities
- Uses exiting DTM points to improve automatic DTM generation
- Uses a surface reconstruction module to capture DTM points in poor texture areas
- On-line visualization tools to monitor DTM points quality
- Borderlines are exploded to avoid edge effects

3.2.3 Profile and Cross-section Extraction

ImageStation Alignment Cross-Sectioning (ISAC) allows the collection of terrain elevation data along scan lines defined relative to horizontal alignments (Figure 6). ISAC supports alignments defined by other roadway design software applications and supports alignments created using MicroStation. Cross-section geometry collected by ISAC can be used with other Intergraph Civil Engineering products, such as InXpress, and can be ported to other products, such as Roadway Design System (RDS).

3.3 Orthophoto Generation

Orthorectification is a process of removing the effects of tilt, relief, and many of the lens aberrations from the standard perspective photographs. ImageStation Image Rectifier (ISIR) is a set of batch utilities designed to be used in the process of orthorectifying aerial photographs and satellite imagery.

The output from the DTM generation process is merged with any other terrain information such as breaklines and spot heights to generate either a "TTN " or "GRD" file. A TTN is a topologically triangulated network, often referred to as a TIN or triangle file, and a GRD file is a raster grid file that stores X, Y, and Z values for regularly spaced posts. The ImageStation Image Rectifier (SIR) product can use either of these two popular formats for the ortho resampling process. The Intergraph DTM product (MSM) can be used to analyze plan or perspective views of topographic features, triangles, surface mesh, contours, and color-coded elevations.

ISIR uses three types of resampling techniques, nearest neighbor, bilinear, and cubic convolution. Intergraph uses the anchor point method, which applies the math model to every n-th pixel, where n is a binary integer (2,4,8,16,32,64...). Pixel locations between the anchor points are interpolated.

As a component of an orthorectification system, ISIR enables users to create a digital orthophoto from an input image that can serve as a backdrop for a GIS, or can be used for heads-up digitizing. ISIR can also be used for generating orthophoto maps. Any ground features collected in stereo 3-D extraction can be displayed in their true orthographic positions directly on top of the newly generated orthophoto. Additional digitizing in 2-D can also be performed directly on top of the digital orthophoto. The ISIR product has the capability to choose output pixel size in ground units or by defining the number of rows and columns in the output image. The user can also define the type of resampling method, the pixel spacing for the anchor points, different tile sizes, the number of overviews (reduced resolution data sets) and how they are processed, and the coordinates and rotation of the output image.

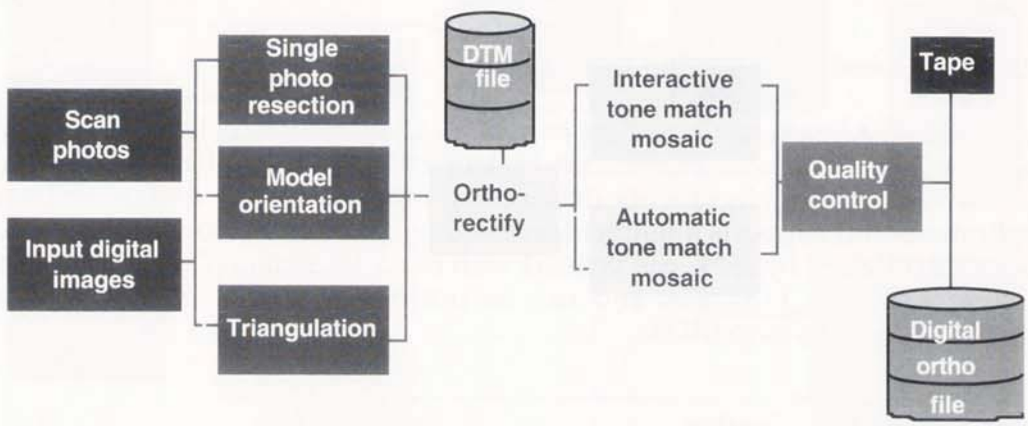

Figure 7. Orthophoto Rectification and Mosaicking Workflow

Main ISIR Features

- Map Projection Transformations - ISIR features commands that enable users to transform files to different world coordinate systems, and to transform images to different map projections.
- Orthorectification - ISIR features several commands designed to orthorectify aerial photographs and satellite imagery.
- Image Transformation - An affine transformation can be performed on Intergraph raster files. This transformation, stored in the raster header file, can then be used to perform a 2-D rubber sheet transformation.
- Stereo - The stereo command creates a stereomate from an input orthorectified image and a DTM file.

- Header File Utilities - The header file utilities provide the capability to copy, load, unload, and show headers and to set the elevation parameters in a header.
- Image Utilities - ISIR's image utilities enable users to minimize and extract images and to transpose Intergraph raster files.
- Output Utilities - The output commands allow users to append a color bar to the bottom of a raster file, to add a color collar around the border of an image, and to insert both destructive and nondestructive corner tick marks.

3.3.1 Mosaicking Tools

There are two options available for mosaicking, an interactive mode and a batch mode. The interactive mode allows the user to interactively mosaic two images at a time. The seam line can be chosen by one of three different ways: 1) interactive placement of points by the operator 2) the selection of existing graphics elements in the design file 3) the software will default to splitting the difference of the two images. The mosaicking module has also a feathering option that blends by weighted averaging. Several options are available for tone matching, including match cumulative frequency, and match mean and standard deviation. ImageStation Imager (ISI) software is ideally suited for image display and enhancement, including tone matching and seamless mosaicking of overlapping orthoimages. ISI achieves the seamless result during mosaicking by applying a feathering algorithm on either side of the seam line in the overlap area between two digital images. The seam can be automatically generated by the software, user-defined, or can use an existing design file element (e.g., a road, river, or boundary). The feathering width is adjustable and does an excellent job of blending one photo into the next without any visual trace of the join.

The batch mosaicking module is a completely automated process that uses multiple orthophotos as input. ImageStation AutoOrtho (ISAO) software mosaics, feathers and, tone matches the multiple orthophotos and outputs a single composite image. The feathering option in ISAO is used to blend the pixels across the mosaic seam lines. ISAO locates the seam lines by building a tile map. The width of the seam line is influenced by the temporary tile size. The tile map is based on the location of zero value pixels which represent fill values in the input images.

4. Other Software Modules

4.1 TRIFID Multi-sensor Triangulation

TRIFID Multi-sensor Triangulation (third-party product - TRIFID, USA) software is the core software and has driver capability specific to SPOT, Landsat, and Aerial modules.

ImageStation Photogrammetric Manager (ISPM) is needed to set up necessary file structures and parameters for these triangulation products. ISPM provides other capabilities such as the setup and maintenance of a photogrammetric project and the ability to read data from a SPOT or Landsat Thematic Mapper digital tape into the system. ImageStation Digital Mensuration (ISDM) is used to perform point mensuration (tie/pass and control) and editing for different sensor imagery (Figure 4).

The SPOT triangulation product provides a sophisticated orbital model of the SPOT satellite system, allowing for highly accurate geodetic positioning. It provides a simultaneous bundle adjustment of up to 84 SPOT level 1-A digital images with a minimal number of control points. SPOT module uses a rigorous orbital mathematical model constrained by the ephemeries data read from the SPOT digital tape and uses a very flexible weighting scheme. This product can work in conjunction with Landsat and Aerial modules for multi-sensor triangulation of different sensor imagery.

The Landsat triangulation product, a simultaneous bundle adjustment with a minimum number of control points, represents the triangulation portion of digital Landsat Thematic Mapper satellite workflows. Landsat module supplies an empirically calculated orbital model of the Landsat satellite system allowing, for accurate geodetic positioning. Finally, Aerial module represents the triangulation portion of aerial imagery workflows.

Main Multi-sensor Triangulation Features

- Fundamental observation equations account for the time dependent nature of the SPOT sensor.
- Has no constraint on acquisition look angles. The only geometric constraint between the SPOT images is that each image must overlap with at least one other image.
- Adjusts any combination of up to a total of 84 level 1-A panchromatic and/or multi-spectral SPOT images.
- Input image data and control point coordinates are in free format ASCII files.
- Extract initial values for exterior orientation parameters from a leader file on standard level 1-A SPOT CCTs.
- Provides default weights for sensor parameters, image coordinates, control points, and tie points in free format ASCII files.
- Computes initial values for tie point coordinates using an Image-to-Ground algorithm intersecting at zero elevation.

- Control points may be assigned individual weights, allowing for a variety of control point sources.
- Diagnostic (check) points are used to evaluate the absolute accuracy of the adjustment results.
- Generate reports with optional listings of the orbital and point data, iteration listings, image residuals, variance-covariance analysis, and other statistical indicators.
- Flags any image points with residuals exceeding three times the adjusted reference standard deviation.
- Triangulation results are compatible with Intergraph's InterMap Analytic (IMA) stereoplotter and InterMap Digital stereoplotter

4.2 Industrial (Close-Range) Photogrammetry

Digital photogrammetry is ideal for terrestrial photogrammetry applications, such as the creation of accurate as-built models of industrial plants and refineries. Digital photogrammetry products are used to create a visual data base of an existing plant that can be exploited by photogrammetrists, plant design engineers, or facility management personal.

As-Built Visualization (ABV) describes the overall solution targeted at plant revamp projects which combine products and services for the capture, processing, analysis, and output of photogrammetric data, and the design information generated from that data. The photogrammetric component, close-range, is created through an onsite survey and the capture of photographic images, which are then scanned to create digital images and processed using digital photogrammetric techniques. This data capture is generally provided by photogrammetry companies to produce a "visual database" (Figure 3). This visual database can be used to generate a 3-D CAD model of the plant by an engineer or designer using the MicroStation-based PLANTGEN (third-party product - Alias, England) product. The created graphic model and the associated intelligent engineering data can be used with Intergraph engineering design applications, such as PDS, VDS, and Design Review, to address related workflows and expand these overall solution offerings (Figure 8).

ABV solution provides functionality and flexibility that allows experts in each part of the workflow to control that portion of the process. Surveyors do the surveying, photogrammetrists do the photogrammetry, and engineers and designers create the as-built model based on the requirements of the design project.

The primary use of this technology will be for plant revamps. Any plant or facility that has the need for an as-built or as-is model is a potential target for ABV. The nuclear power industry is another example of using this application due both to safety factors and the reduced on-site personnel and time that ABV requires when compared with traditional methods.

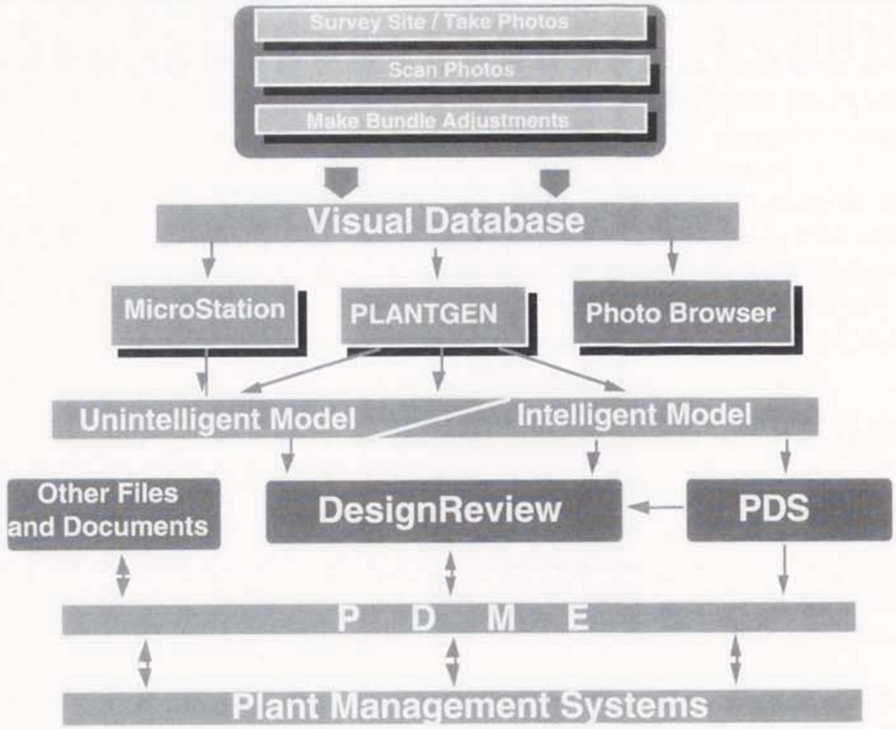

Figure 8. As-Built Visualization System Workflow

5. Summary and Concluding Remarks

An integrated digital production system must integrate all the tools of the digital environment and enhance the real photogrammetric workflows, aerial triangulation, feature and elevation collection, and orthophoto production. The digital workflow provides major benefits in the area of automated measurement. Currently both aerial triangulation and elevation model collection use correlation and auto-measurement techniques to increase productivity. The degree of automation for both workflows continues to improve, for example, automatic breakline detection for elevation collection and completely automatic pass point and tie point measurement for aerial triangulation. The challenge for a digital photogrammetric production system is to integrate these automated techniques with an operator's ability to interactively measure and edit points. Automated feature extraction is still mostly in a research and development stage; however, softcopy provides an environment where these advancements are now very feasible for the future. Advancements for aerial triangulation and elevation collation also represent advancements for digital orthophoto production. Digital orthophotos have become a very popular product, especially for the added value they bring to geographic information systems (GIS) projects.

Digital aerotriangulation is another benefit of the ImageStation line of digital photogrammetry products. This software allows for interactive automated point transfer through image correlation, which means further speed increases for the production workflow. On-line interactive bundle adjustment software will also be included in the next release of the software.

This paper has described the Intergraph Integrated Digital Photogrammetry System, including its unique hardware/software configuration. Its integration in other GIS and Engineering products makes it a highly efficient photogrammetry platform. Its unique user-friendly interface, flexible forms and icons, numerous data editing capabilities, rigorous mathematical models, high-speed raster/vector processing and superimposition, and ergonomic design make the IMD a highly efficient system.

ImageStation's 27-inch, 2-megapixel display, 24-bit true color monitor provides a larger field of view than conventional analytical plotters. Typically the field of view for an ImageStation is more than twice as big as analytical plotters at the same magnification. This allows the operator to look ahead further and work more comfortably. The 27-inch monitor is also well suited for the multiple photo layouts required for the aerotriangulation process. It also has nondestructive vectors, which means an operator can make edits such as deleting or moving a feature without erasing the image(s) behind the vectors.

Digital photogrammetry builds on computing technology. As more and more of the processes are automated, the productivity of the user will continue to increase. A well integrated digital photogrammetry system will yield greater productivity over its predecessors, as well as bringing added value based on the computer technologies.

The ImageStation Digital Photogrammetry Workflow

Compiled by James D. Carswell

Product Marketing Manager - Digital Photogrammetry - Intergraph EHQ - February '96

Abstract

The ImageStation from Intergraph incorporates a suite of hardware and software products specially designed for high production digital photogrammetry and image processing. The following pages will describe the entire ImageStation digital photogrammetry workflow from scanning on the PhotoScan to interior/relative/absolute orientations to DTM/feature extraction to orthophoto production.

<u>*STEP 1*</u> Scanning

The first step in the digital photogrammetry workflow is the scanning of the photos. This step could probably be considered as one of the most important in the entire workflow. The idea of course is to try and completely capture both the true radiometric quality of the aerial film while the same time maintaining its geometry.

The most accurate (< 2*u*m RMS per axis) aerial film scanner available today is the PhotoScan. The PhotoScan is a high-resolution, radiometrically and geometrically precise, flatbed scanning system that converts photographic information from black and white or colour positive or negative aerial film into digital raster image data. The PhotoScan is the result of a co-operative development agreement between Zeiss and Intergraph, Zeiss providing the superior optics and precision mechanics and Intergraph providing the CCD camera, electronics, powerful host workstation, and specialised application software.

The PhotoScan has an optical resolution of 7.5 *u*m. This means that all scanning is done at 7.5 *u*m resolution and then averaged, if the operator requires, to generate an output scan at 15 *u*m, 22.5 *u*m, 30 *u*m, 60 *u*m or 120 *u*m resolution.

Intergraph has investigated measurement accuracy at different scan resolutions and has found that orientation and DTM results carried out digitally on 15 *u*m images are more accurate than those obtainable by analytical plotters. The accuracy achievable on 30 *u*m scans is less than 15 *u*m images however 30 *u*m resolution still provides good results for some photogrammetric applications like stereo feature digitising and orthophoto production. For accurate aerialtriangulation results, 15 *u*m is recommended.

Another advantage of the PhotoScan is its capability for JPEG image compression/decompression. JPEG (Joint Photographic Experts Group) is a sub-working group of both IEC/ISO and CCITT. JPEG has developed an international standard for continuous tone (grey scale or colour) still-image compression.

The image compression is achieved by a series of steps beginning with the subdivision of the image into 8x8 blocks. Next, the blocks are transformed by the Discrete Cosine Transform. The result of the transform is a 8x8 block of transform coefficients. These coefficients are quantised by a variable amount, depending on the position of the coefficient in the 8x8 array. The level of quantisation can be changed by varying the Q-factor (Quantisation or Quality-factor). The quantised coefficients are then run-length encoded and the run-length codes are then Huffman encoded.

The Q-factor is variable between 0 and 300 with a value of 0 meaning no compression. Typically, if a Q-factor of 25 is used, image compression of 3-4 times is achieved (depending on image texture) without any noticeable change in image quality or detail.

Intergraph has incorporated the JPEG algorithm into a JPEG image compression/decompression hardware board. This JPEG board is inside every PhotoScan and allows the imagery to be scanned to disk directly into JPEG compressed format. When the imagery is needed for viewing or other subsequent processing, it first moves in real time from the disk through the JPEG board to get decompressed on-the-fly before being displayed on the monitor. So the imagery is always in compressed format on the disk and decompressed format on the screen or when being processed.

An uncompressed black and white image scanned at 30 *u*m has a file size of about 60 MB. A single colour image scanned at the same resolution will be approximately 180 MB (60 MB for each of the three bands - red, green, blue). This means that a single 2.1 GB internal hard disk will be able to hold 35 uncompressed black and white 30 *u*m images (or 11 uncompressed colour images). With JPEG compression, the number of images that can be stored increases to 105. This conservative estimate assumes only 3 times compression for each image. Currently, a fully configured PhotoScan or ImageStation can hold 45 GB of internal disks which allows for complete projects (hundreds of photos) to be stored and therefore available on-line. Of course this does not take into account the option to further increase storage capacity by connecting additional external disks.

STEP 2 Interior Orientation - ISDO or ISDM

This step can use software module ImageStation Digital Orientation (ISDO) or ImageStation Digital Mensuration (ISDM).

Interior orientation is the process of measuring the fiducial marks on the digital imagery. This measurement process will relate the pixel coordinates of the digital image to the photo coordinate system. This step and all the remaining steps in the workflow are carried out on the ImageStation.

Once the fiducials on the first photo have been measured, all the fiducials on subsequent photos will be automatically measured using image correlation techniques (automatic functionality in ISDM sw only). Image footprints can be automatically generated into a design file allowing the operator the option to select a stereo model by graphically pointing to which images he wants to process.

STEP 3 Relative Orientation - ISDO or ISDM

Relative orientation is the process of measuring (removing x and y parallax of) at least 6 points, in the overlap region on both the left and right photo of a stereo pair. This measurement process will relate the two photos to each other in space and transform the photo coordinates of the measured points into model coordinates.

The point measurement process is facilitated by the ability to measure in both mono and stereo modes at the same time. Also, common points can be locked in one photo while being transferred down or across strips. Automatic point measurement and transfer using image correlation techniques is available in ISDM. Functionality exists for the viewing of up to 6 photos at a time while performing the pass/tie/control point measurements.

All pass points (points tying stereo models together), tie points (points tying strips together), and control points can also be measured during the relative orientation step. If aerial triangulation adjustments are required, all measurements from the relative orientation step can be output to third party adjustment packages like PATB-RS, PAT-MR, BLUH, and BINGO or alternatively, ISDM's own bundle adjustment sw can be used. After adjustments have been made, the results are read back into the ImageStation environment where the exterior orientation parameters will be used to epipolar resample each stereo model.

STEP 4 Absolute Orientation - ISDO or ISDM

If aerial triangulation is not required (because there are at least 3 control points already identifiable in each model), then the process of absolute orientation will be the next step. If all the pass points, tie points and control points have already been measured in relative orientation, then the absolute orientation form needs only to be checked off and the software will calculate the elements of exterior orientation for each photo relative to ground control.

If these points have not yet been measured (x parallax removed), then they can be measured and/or transferred in the absolute orientation environment in the same way as they would have been measured in relative orientation.

<u>*STEP 5*</u> Epipolar Resampling - ISPM

This step uses software module ImageStation Photogrammetric Manager (ISPM).

After the elements of exterior orientation have been calculated for each photo, either from the aerial triangulation adjustment program or directly from absolute orientation, the photos will then be resampled into epipolar format.

Epipolar format is a re-arrangement of the pixels in each digital photo of a stereo model in such a way as to remove all the y parallax. The resulting images will then be stereo ready for 3D feature and DTM collection.

For 30 *u*m images, resampling a stereo model to epipolar format takes about 15 minutes. The resulting files are approximately 60% (assuming a 60% overlap between photos) the size of the original scanned images. To free up disk space, the original images can be removed from disk at this stage as all further processing (except ortho photo production) will be on the resampled images.

After the orientation steps, it is possible for operators to set up the epipolar resampling process to run in batch over night. When they return the next day, production can continue uninterrupted as all models will be set and ready for 3D viewing and digitising.

<u>*STEP 6*</u> 3D Digitising/Feature Collection - ISSD, MSFC, ISDC, ISMT

This step uses modules ImageStation Stereo Display (ISSD), MicroStation Feature Collection (MSFC), ImageStation DTM Collection (ISDC), and ImageStation MatchT (ISMT).

After resampling into epipolar geometry, each stereo model is ready for stereo viewing and digitising. MSFC provides an efficient map feature digitising system that extends standard MicroStation 32 capabilities. It furnishes numerous commands to collect, edit and attribute feature data directly into an Intergraph design file.

Digital terrain models can be collected interactively with ISDC or automatically with ISMT. On-line triangle and contour generation allows the operator to view and manipulate in real time the contours over the collected area while still in the model.

ISMT was originally developed by Dr. Fritz Ackermann's company INPHO from Stuttgart, Germany. This automatic DTM generation program (commonly called MatchT) will, on a 30 *u*m model, collect a DTM at a user specified grid spacing in less than 1 hour (typical times can be less than 1/2 hour/model). This savings in time (as compared to collecting the same area analytically) is one of the main reasons why most photogrammetric and mapping organisations are investing in ImageStation digital photogrammetry today.

STEP 7 Ortho Photo Production - MSM, ISIR, ISI

This step uses software modules MicroStation Modeler (MSM), ImageStation Image Rectifier (ISIR) and ImageStation Imager (ISI).

The output from the DTM generation process of Step 6 is used as input into MSM. Here the DTM will be merged with any other terrain information like breaklines, spot heights etc. to generate what is called a grid file. This grid file is nothing more than another DTM stored in a binary format ready to be used by the ISIR software for generating the orthophoto. MSM can be used to analyse plan or perspective views of topographic features, triangles, surface mesh, contours, and colour coded elevations. Also in MSM is the capability to represent 3D terrain information in a large number of projection and coordinate systems.

After the grid file has been generated in MSM, all the elements are in place (original digital image, orientation parameters, DTM) for creating a digital orthophoto. The orthophoto is created using ISIR and typically takes less than 5 minutes to process (depending on the grid spacing of the DTM and the output pixel size of the orthophoto). ISIR is also capable of orthorectifying satellite imagery. Any ground features collected in stereo from Step 6 can be displayed in their true orthographic positions directly on top of the newly generated orthophoto. Additional digitising in 2D can also be performed directly on top of the digital orthophoto.

Once the orthophoto has been generated, it can be viewed in the image processing software, ISI. This software is ideally suited for image display and enhancement, including seamless mosaicking of overlapping orthoimages. ISI achieves the seamless result during mosaicking by applying a feathering algorithm on either side of the seam line in the overlap area between two digital images. The feathering width is adjustable with 100 pixels on either side of the user defined seam line usually being sufficient to blend one photo into the next without any visual trace of the join.

SUMMARY

The following pages will further expand on the advantages of digital photogrammetry with the ImageStation.

1. The VI-50 is the ImageStation's raster processor with 172 MIPS, 300 MOPS and 18 MFLOPS. With the VI-50, the ImageStation can do real-time stereo roaming and digitising with true colour images and vectors. Roaming is not restricted to any specific window size or image area - roaming can be carried out over the entire model in real time inside any size window. The VI-50 is also used for resampling the raw images (after the orientation process) into epipolar geometry for stereo viewing/digitising and for resampling the raw images into orthophotos. For colour orthophotos, the VI-50 speeds up the resampling time about 3 times as it resamples the three red/green/blue colour bands at the same time. This means a colour digital orthophoto can be produced in about 5 minutes or less.

2. One of the biggest advantages of the ImageStation is the JPEG compression/decompression board. No other vendor of mapping solutions has on-the-fly hardware compression. This means a savings of 3-10 times in disk space. The images are scanned into JPEG (compressed) format directly on the scanner and spend their entire lives in compressed format. When the user wants to view the images on the monitor, the images travel from the disk through the JPEG board and get decompressed on-the-fly to arrive on the monitor in decompressed format. All this is done in real time.

With 3 times compression, a typical 2.1GB disk can hold 105 b/w images scanned at 30 um. Without JPEG, the same disk can hold only 35 b/w images scanned at 30 um. For 3 times compression on colour images, a 2.1GB disk can hold 35 JPEG images compared to only 11 uncompressed 30 um images.

So for any organisation who wants to do production digital photogrammetry, a hardware on-the-fly compression board is a must. Note that these figures quoted above are for just 3 times compression. It is very common that higher compression rates are used without any noticeable loss of detail in the imagery.

Another plus for JPEG compressed imagery is that because the files are smaller, they transfer over the network faster and backup to tape faster.

3. Digital aerotriangulation is another benefit of the ImageStation line of digital photogrammetry products. This software allows for interactive automated point transfer through image correlation which means further speed increases for the production workflow. After measurement, the on-line bundle adjustment can be run to triangulate the block without translation to 3rd party programs.

4. Digital photogrammetry builds on computing technology. As more and more of the processes are automated, the productivity of the user will continue to increase. For example:

Satellite Triangulation (Available now)

- SPOT Stereo Triangulation
  This will allow the user to triangulate SPOT stereo images using only two control points per scene.
- LandSat Stereo Triangulation
  This will allow the user to triangulate LandSat imagery for stereo use with SPOT images. This would be used in areas where the SPOT stereo coverage did not exist.

Terrain Extraction (Available now)

- Match-T with Satellite Imagery
  Enhancements made to the Match-T software to allow its use with satellite images.
- Machine assisted dot-on-the-ground through image correlation

Interactive Automated Feature Extraction (Future)

- Automatic house tracing
- Area "flooding" for water bodies/fields/woods
- Assisted line following for roads

PHODIS Innovations

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ABSTRACT

The contents of this paper are the new applications and functions in the digital photogrammetric image processing system PHODIS. The report on news in PHODIS starts with new functions in PHODIS Base which represents a set of functionalities common to all PHODIS applications. This is followed by a short description of the new, rollfilm-capable photogrammetric scanning system PHODIS SC. Automatic aerotriangulation is implemented in the new PHODIS AT. For DTM-generation, the new tool PHODIS TS applies an integrated approach of preprocessing, automatic DTM-derivation, and postprocessing in a stereo editing environment. The paper concludes with a description of the new model PHODIS ST 10 of the digital stereoplotter.

1. INTRODUCTION

A digital photogrammetric system is supposed to offer to the user the full range of functionality required for production. This starts with the analog to digital (A/D-) conversion of analog images. Based on oriented images, applications such as topographic data acquisition, DTM-generation, and orthoprojection follow. For the purpose of orienting images, methods including aerotriangulation, absolote model orientation, and spatial resection are applied. Finally, the results of production are digital data and map sheets of any form.
These processes represent known procedures in Photogrammetry. There is, however, a specific potential of power of digital systems over analog or analytical systems which is the possibility to generate automatic measuring procedures. Such functionality uses the digital information contained in images in order to perform measurements.
The following focusses on the implementation of these possibilities in new applications and functions in PHODIS. Advantages in the use of digital photogrammetry (DP) are shown.

2. PHODIS

The first step of Carl Zeiss into digital aerial image processing was in 1989 with the presentation of the PS1 PhotoScan photogrammetric scanner (Faust 1989). The extension to a digital photogrammetric image processing system was done in 1991 through the presentations of the digital orthoprojection system PHODIS OP (Mayr 1991) and the system TopoSURF (Krzystek 1991) for the automatic generation of DTM using one stereomodel. The DTM-generation applies a fully automatic measuring method. This capability is one of the main features of DP. The generated DTMs were primarily used in orthophoto-generation. The introduction of the PHODIS ST digital stereoplotter opened the way to do data acquisition on such a device as well. Based on this package, new features and robust automatic procedures are implemented in new PHODIS applications. Figure 1 gives a schematic product overview of PHODIS and expresses the common base.

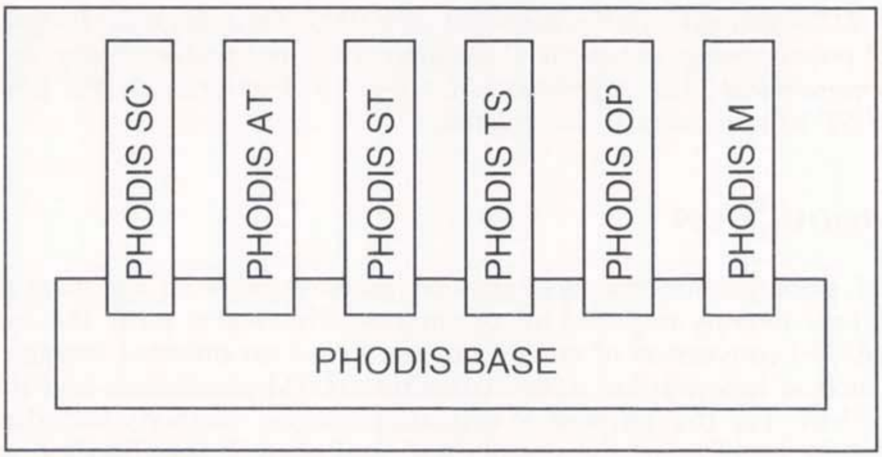

Figure 1: PHODIS product overview

2.1 PHODIS Basis

Automatic interior orientation (AIO)

The automatic interior orientation procedure is integrated into PHODIS Base (Willkomm and Dörstel 1994) which is an essential part of every PHODIS application (see figure 1). The method searches the fiducials by correlating a fiducial pattern with the image in a strategic approach. This way it determines the coordinates of the fiducials in the pixel coordinate system of the digital image (Schickler 1995). AIO is capable of recognizing the rotation of the image in the file. There are 8 situations possible. By localizing an unsymmetry pattern in the image it is possible to determine the situation of the image in the file. Furthermore, AIO can detect if the image is a diapositive or a negative. The robust estimation of the transformation parameters from the pixel coordinate system into the photo coordinate system contains criteria which allow the process to automatically either accept or neglect the results. AIO comes prepared for a variety of aerial cameras.

Automatic relative Orientation (ARO)

The stereo model setup is done either in a one-step procedure, applying the bundle solution for one model, or it is carried out as a two-step procedure with relative and absolute orientations. The latter procedure is commonly used e.g. in analytical stereoplotters. The process of relative orientation is based on the determination of conjugate points, so-called tie-points. This task can be performed in DP by an automatic process and is called the *automatic relative orientation*. Such a principle is integrated in PHODIS. It is composed of several steps the keywords of which are *image pyramids*, *feature extraction*, *feature matching*, *feature tracking*, and *robust parameter estimation* (Tang and Heipke 1994, 1993). ARO reduces the required time for interactive work with the system thus freeing up the operator. Due to the large number of conjugate points, e.g. 200, there is a high redundancy in the adjustment process. This ensures stable results, and, provided that good measurements were possible, one can obtain stereomodels with residual parallaxes of about 3 to 5 µm - a range of values which is comparable to results from relative orientations on analytical stereoplotters. However, the redundnacy usually is an order of magnitude higher in ARO. The absolute model orientation is reduced to the manual determination of ground control points. This procedure is called the manual bundle orientation (MBO) in PHODIS. Tie-point measurements of ARO are imported into MBO as additional observations.

Interfaces

The technology of digital photogrammetry is - with the exception of the scanning system - based on algorithms only and thus based on computers. All applications are software solutions only. The scanner is the only hardware required. The common perception of software is that it has the property of being adapted and extended easily. To a certain extent this is correct. For the user it has the advantage that he can solve special integration tasks himself, if he has access to appropriate interfaces. For this purpose an *open system* is required which allows access to all user-relevant information. PHODIS achieves this by default as it comes with open interfaces to its libraries for import and export of photogrammetric data. Data exchange can take place directly, or via ASCII-files or binary files. The user has the opportunity to access e.g. image data, ground control data, camera data, project data, and model data. With an extra library it is possible to get access to the command syntax of the PHODIS ST digital stereoplotter with the possibility of superimposing colored vectors in the stereomodel.

2.2 PHODIS SC

The requirements for a photogrammetric scanner contain technical and application-specific aspects. Important technical features of such a device are geometric and radiometric quality as well as the quality of color reproduction. From the point of view of the application, the following items are of special interest:

The possibility to *operate the scanner without human interaction* over a longer period of time
The generation of *photogrammetric digital images* for the direct use in other applications

This type of functionality is implemeted in the new photogrammetric scanning system PHODIS SC (Mehlo 1995). The operation without human interaction is possible through the *autowinder*, a retrofittable rollfilm attachment to the scanner base unit. This device allows the use of uncut rollfilm. The user is able to scan images from the roll film in an arbitrary order. The limiting factor is the available disk space. Otherwise the scanner can process in unattended mode. The potential connection to an image archiving system opens the possibility of a highly production-oriented scanning system. This way huge data volumes as used e.g. in automatic aerotriangulation can be handled and processed.
The generation of *photogrammetric digital images* can be achieved in a post-processing step. Here automatic processes are gathered and started as batch jobs. Such processes can be e.g. the generation of image pyramids, the automatic interior orientaiton, or histogram modifications. Storage of flight information and the generation of an overview image are done as well in this step.

2.3 PHODIS AT

One of the main features of DP is the automation of measuring processes by the use of image processing techniques. This has made possible the development of the automatic aerotriangulation (AAT). AAT is presented as a new member of the PHODIS family of applications in PHODIS AT (Mayr 1995). The basic approach of conventional aerotriangulation consisting of the steps *block definition*, *measurement*, and *block computation* remains the same in AAT. However, within block preparation and measurements many changes took place. The method of block computation is unaffected by AAT. Existing bundle block adjustment programs can be continued to be used in AAT.

Block preparation in AAT uses as input data the flight identification of the images, the image numbers, the approximations of the coordinates of the projection centers, and the approximate values of the orientation angles κ. These data determine the geometry of the image block approximately. The block is inspected visually using a wire frame representation of all images in the block. During the block preparation in conventional aerotriangulation the block is tied together by interactively *selecting images*, *selecting tie-points to-*

be-determined, and *pugging*, i.e. doing the *point transfer*. In AAT the block is tied together in the measurement phase automatically.

Prerequisites for automatic measurement in AAT are image pyramids. The connection between the images of the block is done automatically in the higher (lower resolution) pyramid levels. This step is called the *generation of the topology* of the block. The algorithm applied is a modified automatic relative orientation. Due to the fact that only higher pyramid levels are involved, this step can be done for the whole block. Ground control points and new object points are measured manually in the original images. The methods of least squares matching or feature based matching are applied as measurement techniques in manual measurement. The manual measurement mode is part of PHODIS AT and allows the measurment of any type of point e.g. for the purpose of quality control measurements and repeated measurements of already measured points

2.4 PHODIS TS

The automatic generation of digital terrain models (DTM) is almost a standard feature of a DP-workstation. The elevations are derived by a matching process which can be considered as robust and field proven. The DTM-generation is done with PHODIS TS. It contains the components *digital stereoplotter*, *DTM-verification*, and *TopoSURF*.

Digital stereoplotter

The functionality of the digital stereoplotter is used as the tool for model setup. It also enables this application to perform interactive DTM-preprocessing and DTM-postprocessing which in combination represent the DTM-verification. The ability of superimposing colored vectors in stereo offers the visual inspection of the DTM itself. Thus, for an environment for DTM-generation the digital steroplotter is required.

DTM-Verification

This component of PHODIS TS kind of triggers the main work flow in automatic DTM-generation. DTM-verification requires a stereomodel in which, in the DTM-preprocessing step, three-dimensional morphological data are collected. The following morphological features are of special interest.

Points of singularity
Break lines
Cutout area polylines

Morphological information is of importance to the DTM-generation process. It defines the constraints within the derivation of the raster-DTM. DTM-postprocessing, better called quality control of the DTM, takes the resulting raster-DTM and analyzes it. It is possible to superimpose in color the DTM over the stereomodel. Visual inspection is then carried out. DTM-points can be picked, moved, deleted, measured additionally or simply inspected.

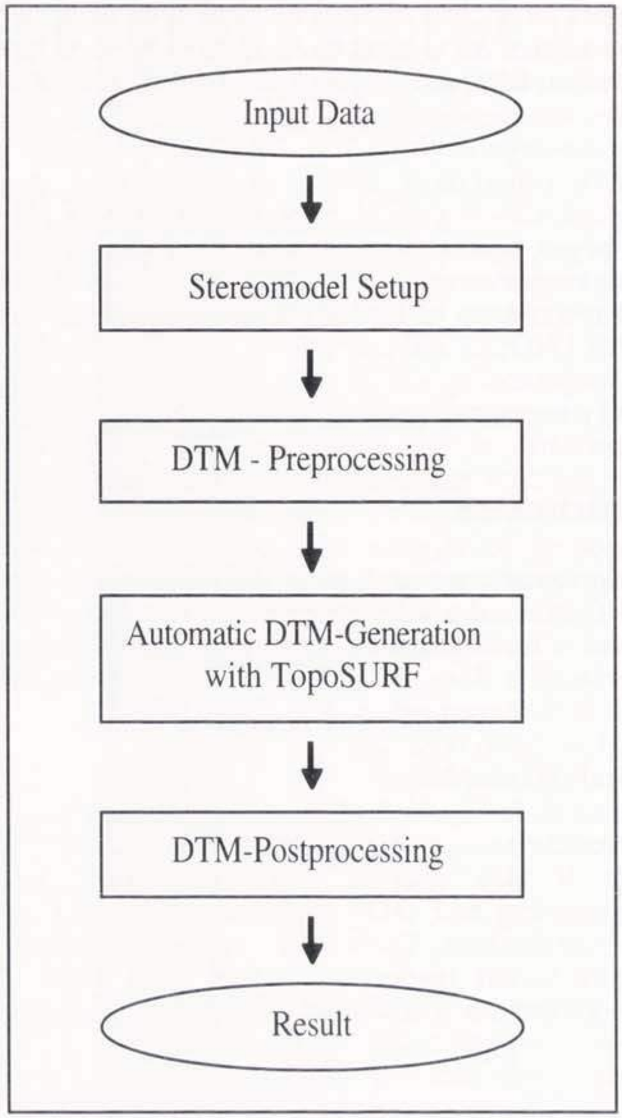

Figure 2: PHODIS TS main components

TopoSURF

The automatic DTM-generation is composed of the four steps *image pyramid generation, feature extraction, feature matching* , and *robust finite element adjustment* for the raster-DTM-generation. The procedure is discussed in detail e.g. in Krzystek 1991.

With this environment the user can easily collect additional information, start the automatic DTM-generation process, and perform quality control. The stereo capability is an essential part of this concept. The raster-DTM can be used in PHODIS OP or for on-line elevation interpolation in PHODIS M.

2.5 PHODIS ST 10

The digital steroplotter PHODIS ST is now available in two models. In both cases the computer platform is Silicon Graphics (Dörstel and Willkomm 1994). The models differ in the way thy display the stereomodel.

PHODIS ST 10 moving image fixed cursor (MIFC)
PHODIS ST 30 fixed image moving cursor (FIMC)

PHODIS ST 10 is new. The images are moving in subpixel steps, and the floating mark is fixed in the center of the field of view. In addition to this capability, PHODIS ST 10 can display stereo scenes without having the requirement of pre-computing epipolar images. This saves computing time which, depending on the image parameters and computer speed, can be 30 or more minutes per image. It also saves disk space which can add up to several hundreds of megabytes of savings. Dynamic measurments especially e.g. contour line following are improved by this mode of displaying stereo scenes in a digital stereoplotter.

3. CONCLUSIONS AND OUTLOOK

PHODIS offers all appplications and function of a powerful digital photogrammetric product family. The homogeneous data flow is given on a standard hardware platform. Automatic procedures are integrated wherever they are robust. They are a fundamental part of the concept behind PHODIS. Currently the requirement for huge amounts of storage capacities in some applications is still an open issue. The use of data compression methods might be a solution to a certain extent. However, non-reversible data compression techniques - and only those deliver acceptable data reduction values - can result in unacceptable loss of image information (Jaakola and Orava 1994). An alternative to this approach might be the implementation of a jukebox-based data archiving system. Storage media can be e.g. EXAByte, DAT, or rewritable magneto-optical CDs. Such a system could be connected to the scanner system which appears to be very helpful in unattended scanning mode. An alternative to a jukebox system can be a disk array. In conjunction with aerotriangulation, another use of such a mass storage device is feasible. For the time being, the integration of field experience and further robust automatic procedures are important to DP. The operator is freed more and more from standard tasks in order to use his experience to take the decisions which an algorithm is not yet capable of.Automatic ground control point recognition, object extraction and line following in arial large scale images are amongst other subjects main areas of focus to the research community e.g. Heipke et al 1994, Gülch 1994, Fuchs 1995. PHODIS is prepared to implement such features.

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28 *Koen, L. A.; Kölbl, O.* (ed.): Proceedings of the OEEPE-Workshop on Data Quality in Land Information Systems, Apeldoorn, Netherlands, 4–6 September 1991. – Frankfurt a. M. 1992, 243 pages with 62 figures, 14 tables and 2 appendices.

29 *Burman, H.; Torlegård, K.:* Empirical Results of GPS – Supported Block Triangulation. – Frankfurt a. M. 1994, 86 pages with 5 figures, 3 tables and 8 appendices.

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B. Special publications

– Special Publications O.E.E.P.E. – Number I

Solaini, L.; Trombetti, C.: Relation sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). I^ère^ Partie: Programme et organisation du travail. – *Solaini, L.; Belfiore, P.:* Travaux préliminaires de la Commission B de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.) (Triangulations aériennes aux grandes échelles). – *Solaini, L.; Trombetti, C.; Belfiore, P.:* Rapport sur les travaux expérimentaux de triangulation aérienne exécutés par l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (Commission A et B). – *Lehmann, G.:* Compte rendu des travaux de la Commission C de l'O.E.E.P.E. effectués jusqu'à présent. – *Gotthardt, E.:* O.E.E.P.E. Commission C. Compte-rendu de la restitution à la Technischen Hochschule, Stuttgart, des vols d'essai du groupe I du terrain d'Oberriet. – *Brucklacher, W.:* Compte-rendu du centre «Zeiss-Aerotopograph» sur les restitutions pour la Commission C de l'O.E.E.P.E. (Restitution de la bande de vol, groupe I, vol. No. 5). – *Förstner, R.:* O.E.E.P.E. Commission C. Rapport sur la restitution effectuée dans l'Institut für Angewandte Geodäsie, Francfort sur le Main. Terrain d'essai d'Oberriet les vols No. 1 et 3 (groupe I). – I.T.C., Delft: Commission C, O.E.E.P.E. Déroulement chronologique des observations. – Photogrammetria XII (1955–1956) 3, Amsterdam 1956, pp. 79–199 with 12 figures and 11 tables.

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Solaini, L.; Trombetti, C.: Relations sur les travaux préliminaires de la Commission A (Triangulation aérienne aux petites et aux moyennes échelles) de l'Organisation Européenne d'Etudes Photogrammétriques Expérimentales (O.E.E.P.E.). 2^e^ partie. Prises de vues et points de contrôle. – *Gotthardt, E.:* Rapport sur les premiers résultats de l'essai d'«Oberriet» de la Commission C de l'O.E.E.P.E. – Photogrammetria XV (1958–1959) 3, Amsterdam 1959, pp. 77–148 with 15 figures and 12 tables.

– *Trombetti, C.:* Travaux de prises de vues et préparation sur le terrain effectuées dans le 1958 sur le nouveau polygone italien pour la Commission A de l'OEEPE. – Florence 1959, 16 pages with 109 tables.

– *Trombetti, C.; Fondelli, M.:* Aérotriangulation analogique solaire. – Firence 1961, 111 pages, with 14 figures and 43 tables.

– Publications spéciales de l'O.E.E.P.E. – Numéro III

Solaini, L.; Trombetti, C.: Rapport sur les résultats des travaux d'enchaînement et de compensation exécutés pour la Commission A de l'O.E.E.P.E. jusqu'au mois de Janvier 1960. Tome 1: Tableaux et texte. Tome 2: Atlas. – Photogrammetria XVII (1960–1961) 4, Amsterdam 1961, pp. 119–326 with 69 figures and 18 tables.

– „OEEPE – Sonderveröffentlichung Nr. 1"

Gigas, E.: „Beitrag zur Geschichte der Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – *N. N.:* „Vereinbarung über die Gründung einer Europäischen Organisation für photogrammetrische experimentelle Untersuchungen" – „Zusatzprotokoll" – *Gigas, E.:* „Der Sechserausschuß" – *Brucklacher, W.:* „Kurzbericht über die Arbeiten in der Kommission A der OEEPE" – *Cunietti, M.:* „Kurzbericht des Präsidenten der Kommission B über die gegenwärtigen Versuche und Untersuchungen" – *Förstner, R.:* „Kurzbericht über die Arbeiten in der Kommission B der OEEPE" – „Kurzbericht über die Arbeiten in der Kommission C der OEEPE" – *Belzner, H.:* „Kurzbericht über die Arbeiten in der Kommission E der OEEPE" – *Schwidefsky, K.:* „Kurzbericht über die Arbeiten in der Kommission F der OEEPE" – *Meier, H.-K.:* „Kurzbericht über die Tätigkeit der Untergruppe „Numerische Verfahren" in der Kommission F der OEEPE" – *Belzner, H.:* „Versuchsfelder für internationale Versuchs- und Forschungsarbeiten." – Nachr. Kt.- u. Vermesss.-wes., R. V, Nr. 2, Frankfurt a. M. 1962, 41 pages with 3 tables and 7 annexes.

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– *Neumaier, K.; Kasper, H.:* Untersuchungen zur Aerotriangulation von Überweitwinkelaufnahmen. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. Nr. 2, Wien 1965, 4 pages with 4 annexes.

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Neumaier, K.: „Versuch »Bedford« und »Waterbury«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE" – „Versuch »Schweizer Block«. Gemeinsamer Bericht aller Zentren der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., R.V, Nr. 13, Frankfurt a. M. 1966, 30 pages with 44 annexes.

– *Stickler, A.; Waldhäusl, P.:* Interpretation der vorläufigen Ergebnisse der Versuche der Kommission C der OEEPE aus der Sicht des Zentrums Wien. – Österr. Z. Vermess.-wes., OEEPE-Sonderveröff. (Publ. Spéc.) Nr. 3, Wien 1967, 4 pages with 2 figures and 9 tables.

– „OEEPE – Sonderveröffentlichung Nr. 4"

Schürer, K.: „Die Höhenmeßgenauigkeit einfacher photogrammetrischer Kartiergeräte. Bemerkungen zum Versuch »Schweizer Block« der Kommission E der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M., 1968, 25 pages with 7 figures and 3 tables.

– „OEEPE – Sonderveröffentlichung Nr. 5"

Förstner, R.: „Über die Genauigkeit der photogrammetrischen Koordinatenmessung in bergigem Gelände. Bericht über die Ergebnisse des Versuchs Reichenbach der Kommission C der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1969, Part I: 74 pages with 9 figures; Part II: 65 tables.

– „OEEPE – Sonderveröffentlichung Nr. 6"

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Weitere Ergebnisse des Meßversuchs „Oberriet" der Kommission C der OEEPE. *Härry, H.:* „Messungen an nicht signalisierten Geländepunkten im Versuchsfeld «Oberriet»" – *Stickler, A.; Waldhäusl, P.:* „Graphische Auswertung nicht signalisierter Punkte und Linien und deren Vergleich mit Feldmessungsergebnissen im Versuchsfeld «Oberriet»" – *Förstner, R.:* „Weitere Ergebnisse aus Koordinatentransformationen des Versuchs «Oberriet» der Kommission C der OEEPE" – *Schürer, K.:* „Streckenvergleich «Oberriet»." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1975, 116 pages with 22 figures and 26 tables.

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  Timmerman, J.; Roos, P. A.; Schürer, K.; Förstner, R.: „Über die Genauigkeit der photogrammetrischen Gebäudevermessung. Bericht über die Ergebnisse des Versuchs Dordrecht der Kommission C der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1983, 131 pages with 14 figures and 36 tables.

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  Schürer, K.: „Über die Genauigkeit der Koordinaten signalisierter Punkte bei großen Bildmaßstäben. Ergebnisse des Versuchs „Wien" der Kommission C der OEEPE." – Nachr. Kt.- u. Vermess.-wes., Sonderhefte, Frankfurt a. M. 1987, 84 pages with 3 figures, 10 tables and 42 annexes.

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- *Cunietti, M.; Inghilleri, G.; Puliti, M.; Togliatti, G.:* Participation aux recherches sur les blocs de bandes pour la cartographie à grande échelle organisées par la Commission B de l'OEEPE. Milano, Centre CASF du Politecnico. – Boll. Geod. e Sc. affini (XXVI) 1, Firenze 1967, 104 pages.
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- *Cunietti, M.:* Résultats des recherches expérimentales organisées par la Commission B de l'OEEPE au cours de la période 1959–1966. Résumé du Rapport final. – Présenté à l'XI^{e} Congrès International de Photogrammétrie, Lausanne 1968, Comm. III (en langues française et anglaise), 9 pages.

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