

OPTIMISING THE WORKFLOW IN A HYBRID PRODUCTION SYSTEM OF ANALYTICAL AND DIGITAL PRODUCTION OF GEODATA USING AERIAL PHOTOGRAPHS

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ABSTRACT:

Today, mapping technologies are in the midst of transition, from analogue and analytical to digital. The move to digital is being driven by the desire to increase production capability through computer automation and taking advantage of new methods, procedures and technologies. During the transition, two or more production lines may be run simultaneously with all the associated complexities. The mapping production environment is thus becoming increasingly complex. In the past, there have been many successful introductions and changeovers of technology where the new, typically over a period of time, replaced the old. Is this truly the case for the current move to digital?

This project is an attempt to running both digital and analytical photogrammetric mapping production lines in a modern mapping company. The study seeks to generate geospatial data using the two systems in order to find out which of the two can lead to more flexible map production, at a reduced cost and reduced turnaround time. The obtained results were analyzed and evaluated according to the following criteria: accuracy, flexibility, time (fatigue) and cost/support.

The main findings of this project showed that, despite the encouraging results reported in the literature, only the orthophoto production is successfully produced using fully automatic approaches. Analytical Photogrammetry (AP) is still a significant production technology for feature extraction, digital terrain model generation and large-scale mapping.

The results achieved so far indicate that aerial triangulation (AT) can equally well be performed on both the analytical and the digital photogrammetry workstation (DPW) with 24 μ m pixel size images. However, the efficiency of digital aerial triangulation (DAT) mainly depends on the type of terrain and image scale. Human intervention becomes significant in areas like mountainous regions, dense urban areas, forest areas and uniform textured terrain. In such situations, DAT takes more time than analytical aerial triangulation (AAT) or simply will not work at all.

The results of the digital terrain model (DTM) from the two systems are almost the same but more time was spent on the DPW due to the density and congestion of structures within the project area. However, in areas where the terrain is open and less rugged, automatic DTM performed very well.

For feature extraction, there is no doubt that analytical plotter still reigns. Despite the fact that from my results there was not much difference in accuracy between the analytical and the 24 μ m pixel size images on the DPW, the interpretability on the DPW was not as easy as it was on the analytical plotter. The project also looks at the issue of system integration. Where AT and DTM performed on analytical plotter was successfully transferred onto the DPW for orthophoto production. Based on the above results, a production line was designed to achieve diversity in the production process such as AT, DTM, feature extraction and orthophotos, for more business opportunities.

INTRODCTION

Problem definition

Over the past ten years, The Survey Department of Ghana in collaboration with private mapping organizations in the country and other foreign agencies have been addressing the problem of the lack of digital maps in the country very seriously.

Rudan Limited, one of the leading mapping organizations in the country, has been producing Topographic maps at scales, 1:2,500 and 1:5,000 from aerial photographs for the past twelve years using analytical plotters (Leica SD 2000 and Zeiss P1) and Wild A8 an analogue plotter interface to PC through encoders. In an attempt to help solved the above problem RUDAN Limited acquired Leica Helava/Socet Set system to run both analytical and digital systems parallel to find out how both systems could be run to complement each other to enhance production, since this can lead to more flexible map production, reduce costs and turnaround time due to versatile data sources and process automation (Xiaopeng and Baker, 2000).

The major influence for the development of a digital photogrammetric production line was due to:

- Increasing demand for digital data
- Technical progress and innovation by new techniques and systems
- Efficiency to meet the market requirements for fast and high quality data production
- Chance for innovation by new type of products and services, and its flexibility.

Prior work

Many of today's Mapping Companies are in the mist of transition to digital technology from analogue and analytical technologies. In the last couple of years, there have been great changes in photogrammetry. Digital photogrammetry (DP) have been introduced in practice and caused a considerable increase in productivity due to the degree of automation. In the late 1980s, the first commercially available digital plotter, the Kern DSP1, was introduced (Wolf and Dewitt, 2000). Most of the photogrammetric workstations come from the firms Intergraph, Leica/Heleva (L/H) Systems and Zeiss. Furthermore, the firm Inpho in Stuttgart has also achieved important development work.

In order to give practicing surveyors of all these development, The European Organization for Experimental Photogrammetric Research (OEEPE) organized a workshop in June 1999, Champs-sur-Marne, on the topic 'Automation in digital photogrammetric production'. At the workshop, many papers drew the attention of the current situation of the extent of automation in digital photogrammetric productions. Among the papers was one titled 'DTM derivation at Ordinance Survey Ireland (Osi)' by (Cory et al., 1999). The paper emphasizes that despite the debate elsewhere, the use of digital photogrammetry at "Osi" has been an unqualified success. The contributions of Xiaopeng and Baker (2000) showed that digital technology is still in a development stage and not mature enough to replace all analytical counterparts completely. They stated that, "Running both systems is a necessary bridge to a full digital mapping environment".

However, Kölbl and Crosetto (1996) conducted a comparison test with digital photogrammetric workstations (DPWs) (ImageStation, Heleva, DSW100) and analytical plotter (BCI). They showed the efficiency of the digital plotters, allowing an improvement of productivity by a factor of about 3 compared to that on the analytical plotter. Kaczynski and Ziobro (1999) also performed a comparison test of AT using Planicom P-1 (analytical) and ImageStation (digital) From their result, it was concluded that DAT is about 20% better than the results of analytical aerial triangulation (AAT).

There are other interesting articles in many journals, addressing the issue of integrating analytical and digital photogrammetric systems. An article written by (Kirwan, 1997) stated that, Ordinance Survey Ireland a National Mapping Agency, initially adopted analytical photogrammetry (AP), but in 1992 it changed to accept DP when it became evident that this was the technology of the future. However, major development is still needed in stereo feature extraction to achieve further gains. Due to the awareness created globally by some mapping organizations dealing with both analytical and digital photogrammetric systems at international conferences and seminars, intensive research mounted for the past 10 years have been yielding very good results. The European Organization for Experimental Photogrammetric Research (OEEPE) has made a significant attempt at dealing with development and the practical application of digital photogrammetric workstations (DPW) and also the degree of automation in digital photogrammetric production.

Objectives of the research

The objectives of the project are as follows:

- To determine which of the two system is more efficient and effective for a particular photogrammetric production process and sub-processes, in terms of accuracy (positional and thematic), flexibility, time used (fatigue) and cost.
- To investigate how to integrate the two systems to achieve maximum outputs.

Resources

Data input: For this study, 27 digital images covering the south-eastern part of Accra the capital town of Ghana were used for the digital Photogrammetric system and diapositives covering the same area were used for the analytical system.

Hardware: Vexell Ultra Scan 5000, Photogrammetric Scanner, was used to scan the diapositives at 24 μ . The digital production processes were performed on Leica / Helava Digital Photogrammetric Workstation. On the other hand, analytical productions were performed on SD 2000 from Leica.

Software: The following software were used during the research period: Operating system used was Windows 2000. AP32 Stereo Orientation, aerial triangulation (AT) and digital elevation model (DEM) System (AP32 Version 2.6l) was used for orientation and AT on the analytical plotter. PAT-B aerial triangulation bundle adjustment program KORK for DTM generation, feature extraction and editing of feature data on the analytical plotter. Softcopy Exploitation Tools (Socet Set) version 4.3.1 software for digital photogrammetric workstations, which lets you

perform all photogrammetric operations, such as, AT, 3-D feature, DTM extraction and Orthophoto generation Orima and CAP “A” as an adjustment program on the digital system.

PRO600 is LH Systems' state-of-the-art package for feature collection and editing with Bentley MicroStation. PRO600 mapping software provides all mapping data parameters such as signs, symbols, colours, line thickness, user-defined line-types and forms. ArcView 3.2A for visualization

METHODOLOGY

Experimental set up on the Analytical Plotter (SD 2000)

AP32 a Stereo Orientation, aerial triangulation (AT) and digital elevation model (DEM) System was used for orientation and AT (measurements of photo coordinates) on the analytical plotter. PAT-B an aerial triangulation bundle block adjustment program was used to adjust the measured photo coordinates to calculate their ground coordinates. KORK digital mapping software was used for DTM generation, feature extraction and editing of feature data on the analytical plotter.

Experimental set up on the Digital Workstation (Leica Heleva)

On the Digital Workstation, Softcopy Exploitation Tools (Socet Set) version 4.3.1 software for digital photo-grammetric workstations, which lets you perform all photogrammetric operations, such as, AT, 3-D feature, DTM extraction and Orthophoto generation was used for the Orientations, triangulation and DTM generation. PRO600 is LH Systems' state-of-the-art package for feature collection and editing with Bentley MicroStation. PRO600 mapping software provides all mapping data parameters such as signs, symbols, colours, line thickness, user-defined line-types and forms. This mapping software was used to capture the features. The generated DTM and the captured features from both systems were exported to ArcView 3.2A for visualization.

Integrating Analytical and Digital Systems

The previous sections have been used to describe the way the experiments were performed on the analytical and digital systems. Now, this section is dedicated to the integrating aspect of the project. That is, how to transfer data from one system to the other to continue with production.

DTM Import: Kork digital Mapping software was used to generate the DTM on the analytical plotter. A KORK – translator – KDMDXF used to translate the generated DTM into an AutoCAD DXF format. The file was then converted into ASCII DTM, using ArcView extension Cad Reader to read the DXF DTM file in ArcView. The DTM theme was converted to a shapefile. Then the Xtools Extension was used to convert the shapefiles to centroids (i.e., make a new point theme based on the center points on the input theme features). The XY coordinates Extension was then applied to add X and Y coordinates of features to attributes tables. to be able to import this file into the Socet Set on the DPW.

Aerial Triangulation (Hybrid): The measured photo coordinates on the analytical plotter was exported in PATB into the ORIMA software on the DPW. CAP A, a Bundle block adjustment program within the ORIMA software was used to run the bundle block adjustment on the imported photo

coordinates. After the Bundle block adjustment has been performed you only has to carry out inner orientation and all the images can be seen in three dimensions.

ANALYSIS AND EVALUATION

Analysis of the results

The results achieved through the research were analyzed and evaluated with the following criteria: Geometric Accuracy, Flexibility (ease of operation), Time (fatigue), Support and Cost.

Comparison of geometric accuracy: The various photogrammetric processes performed on each system were passed through quality control to assess their geometric accuracy. For the quality control, the results from the analytical and the DPW with 24-µm-image resolution were compiled to weigh up the two systems.

Aerial triangulation

The accuracy potentials of AT using DPW and analytical plotter were analysed

Evaluation: A convenient accuracy indicator for blocks is the planimetric ($\mu(x, y)$) and height ($\mu(z)$) accuracy of the adjusted block coordinates is expressed in units of sigma naught (σ_0 : the estimator of the variance factor). In my case considering the ground control distribution in the block we have:

$$\mu(x, y) = 0.9 \sigma_0 \quad (1)$$

$$\mu(z) = 1.3 \sigma_0 \quad (2)$$

The estimator of the variance factors (σ_0), an outputs of PATB for photo scale of 1:10,000 are:

Analytical (σ_0) = 7.11 µm in image coordinate system and 0.0711 m in the terrain.

DPW with 24 µm resolution (σ_0) = 7.45 µm in image coordinate system and 0.0745 m in the terrain.

Applying equations 1 and 2 the RMSE for the planimetry and the height were calculated. The details of the results are summarized in Table 1 below.

RMSE	Analytical	Digital
Sigma nought (σ_0) (m)	0.0711	0.0745
XY (m)	0.0640	0.0671
Z (m)	0.0924	0.0969

Table 1: Results of bundle block adjustment from PATB

In general, the accuracy achieved for planimetry and height on analytical and digital system is satisfactorily. With DAT, the same range of sigma naught was achieved on the DPW (with 24 µm resolution) just as for AAT though the time spent on DAT is about two (2) times less than that spent on the AAT even though the number of observations increases on the DPW.

DTM

With the aim of evaluating the two systems DTM (edited and unedited) generated on the DPW and that generated on the analytical plotter were analyzed. The DTM in the two cases were used to generate spatial contour lines with intervals 2.5m using ArcView GIS 3.2a.

The accuracy of the DTM generated from both systems was calculated using the Empirical formula. The results are summarized in Table 2

RMSE	Analytical	24µm images (edited)	24µm images (unedited)
Σz [height] (m)	0.362	0.416	5.703

Table 2: Accuracy of analytical and digital DTM

From Table 2 it was realized that the accuracy of the automatic DTM is lower than that manually collected on the analytical despite the fact that on the DPW the grid spacing chosen in effect increased the number of mass points in digital 50m-grid compared to that on the analytical 25m-grid. This may be due to the type of surface, its slope variation and type of ground cover. Also the quality of the images used may account for the lower accuracy though the difference is insignificant.

Another factor is, the unedited automatic generated DTM from DPW produces very poor results justifying the statement made by (Gabet, 1996); “the automatic generation of DTM in built-up or dense forest with considerable height-difference areas cannot produce satisfactory results without additional human involvement. For visual representation of the spatial contour refer to Appendices A-5, A-6 and A-7. It was realized that the spatial contours from analytical plotter predict the terrain much more accurate though more time was spent on editing.

Feature Extraction

Based on my experience with the two systems as far as this project is concerned digitized image has lower interpretability than the analogue diapositives. Moreover there is a direct relationship between the extent of interpretability and the scanning resolution of photographs. According to Messelu (1995), interpretability deteriorates as the pixel size increases for a given photo scale.

Feature extraction on the DPW compared to that on an analytical plotter is not very encouraging. During feature extraction on the DPW, interpretability was a problem due to the fact that stereo viewing on DPW is not as acute as on the analytical plotter environment even with imagery scanned at 24 µm. Geometric positioning is more accurate in analytical plotters because of a higher measuring resolution. Refer to Table 3 for Root Mean Square Error for the feature extraction.

RMSE	Analytical	Digital
XY (m)	0.197	0.765
Z (m)	0.231	0.864

Table 3: Root mean square error for feature extraction

For the visual representation of feature extraction on the two systems refer to appendices A-8 and A-9. At present, the major limitations of DPW are low quality of digital images, caused by the relatively large pixel sizes (10-50 µm). For manual image interpretation and extraction of the terrain features, a digital system can hardly be justified. The gain is very modest, whereas the loss in image quality and thus the reduced information content can be great.

Flexibility (ease of operation)

Practically Digital Photogrammetric Workstations (DPW) are very flexible and versatile due to the degree of automation of most of the processes. When operating DPW the operator has the flexibility of body movement to view the keyboard and the monitor thereby reducing body fatigue and increases the operator freedom of eye movement thus reducing eyestrain. The operator is more comfortable for longer periods of time while working on a DPW system, which help to heads-up operation. Superimposition of vectors over imagery concurrently on the DPW facilitates map updating and editing.

Another important factor is that an operator can occupy any workstation (if licenses are available), and imagery may be shared, e.g. DTM collection occurring at the same time as feature collection thus facilitating production. The overall impact on through time is significant.

However, it was also generally agreed that stereo viewing on DPW is not as acute as in the analytical plotter (AP) environment even with imagery scanned at 24-microns. The resolution of the computer screen, the stereo technology and jitter while roaming through the imagery are some of the differences. Placing the cursor onto the ground with DPW is not as comfortable when directly compared to AP technology. In order to achieve a comfortable visual environment, just like on the analytical plotter visual atmosphere, normally result in the operator zooming far into the imagery on the DPW “to get visual comfort” and in effect reduces efficiency. Another problem encountered when using the DPW is the effect of the light source; this has the most significant effect on fatigue and eyestrain.

On the other hand analytical system requires that the operator should have experienced and basic photogrammetric knowledge since most of its processes is manually performed. Viewing the diapositives directly through a binocular (train) optics for a longer period can lead to operator’s discomfort. However, one of the most important items for the comparative study of analytical and digital system concern the image quality in conjunction with the field of view. For image interpretation, it is necessary to identify concurrently the feature of interest and its context. This however, requires high image quality especially for small terrain features. The field of view and the image quality strongly influence the certainty of image interpretation. Here analytical systems perform far better compared to the digital systems due to the direct viewing of the images through the oculars of the plotter.

Time (fatigue)

The total elapsed time acquired for the two systems excludes setting up the project, ground control / camera calibration file preparation and image importation (only on digital system). These results were analyze using one (1) model.

Time needed for individual procedures on the two systems are presented in Table 4.

Processes	Analytical (Minutes)	Digital (Minutes)
Scanning		5
Orientations	15	10
Aerial triangulation	60	30
DTM	60	120
Feature extraction	120	240
Total time (without scanning)	4hrs. 15 mins.	6 hrs.40m
Total time (with scanning)	4hrs. 15 mins.	6 hrs.45m

Table 4: Photogrammetric processes and elapsed time

Comparing the overall time spent on the analytical plotter to that spent on the DPW the time difference is noteworthy. Nevertheless, scanning time can be compensated for if the data will be used for photogrammetric processes where digital is superior to analytical then time gain through automation will cancel scanning time.

The time needed for orientations on the analytical system is more than that on the digital system. The reason is, on the analytical system one has to place the diaposives on the plate carrier for every model and also has to manually place the measuring mark on each fiducial mark although the machine will drive the measuring mark to an approximate location of the fiducial marks after measuring 2 fiducials. Another factor is that analytical plotter needs time to travel from one fiducial mark to the subsequent one. However, on the digital system, no diapositives are required, once the scanned images have been imported onto the DPW; the images can be displayed at any time. Automatic fiducial measurement (not always) is possible after manually setting the extraction cursor close to the first two fiducial marks. Another important factor in the DPW is, once interior orientation (IO) is performed on an image, its parameters are included in the definition of the pixel's coordinates. This relieves the operator from re-establishing the IO in the case of re-measurement of previously used imagery. However, on the analytical system, once a model has been removed from the system and has to be re-measured, IO has to be performed again.

Efficiency of DAT mainly depends on the type of the terrain, image quality, scanning resolution and image scale. Human intervention becomes significant in difficult terrain types like mountainous regions, dense urban areas, forest areas and uniform textured terrain where the algorithm fails to locate conjugate points. In such a situation automatic AT takes more time than analytical triangulation or simply will not work at all (Xiaopeng and Baker, 2000).

Since the mapping area for my research is plain but partly built-up, the time needed for DAT was about 2 times less than that needed to perform the same work on the analytical plotter, though the number of observations increased (5x5 pattern / image in digital comparing to 3x3 in analytical). This is due to the fact that most of the processes are automated hence requires less human interaction. Automation in AT leads to an increased in production rate as well as achieving a homogeneous performance.

The time needed for DTM captured manually on the analytical was about 2 times less than that automatic generated. The time difference for the DTM on the two systems is due to the fact that about two-third of the area is built-up hence post processing of the automatic DTM offer many problems when using the interactive terrain editing due to the large number of blunders in the measurements. However, in areas where the terrain is open and flat automatic DTM performed very well.

Feature extraction is one area where automation is still not very appreciable. Feature extraction or stereo compilation, is the core activity of photogrammetric mapping, at which analogue and analytical systems excel. In conventional photogrammetric systems this task is completely done by human operator. DPW technologies do not offer any significant performance advantages for feature collection at the present time. Feature collection is still an interactive manual process performed on both the AP and DPW. Due to the high-quality optics and a large field of view in the analytical system; effective manual

image interpretation was achieved. Hence the time needed for compilation on the analytical plotter is less than that on the DPW due to the fact that interpretation requires a simultaneous perception and analysis of the specified terrain features and their context.

Support and Cost

Relating to the support and cost of running digital and analytical systems the following factors were considered.

- Image acquisition
- Personnel and equipment rates
- Production time

Digital Photogrammetry (DP) requires digital images, which are obtained directly by using electronic cameras or indirectly by scanning existing aerial photographs. Nowadays, the most used input images are scanned aerial photographs since digital cameras have not yet equalled aerial cameras in terms of performance, resolution, and robust operability. However, the cost of scanners or its services push the initial cost of DP too high for some tastes (Walker, 1996). For higher accuracy and better interpretability, where a high scan resolution is required, scanning becomes more expensive and thus storage. Nevertheless, if the data will be used for photogrammetric processes, which can be fully automated, then the time gain through automation will compensate the cost spent on scanning. A comparison of the cost for analytical and digital systems is rather ambiguous, because their architectures and capacities may differ widely. Photogrammetric hardware of the analytical systems is more expensive than that of the digital systems. However, the latter require in addition extensive image processing software, mass storage devices for images, fast communication lines, powerful processors, and high quality image display monitors. AP technology requires periodic calibration and mechanical maintenance. This is usually performed on a yearly basis to ensure accuracy and prolong life of the equipment. Software maintenance is also required but to a lesser degree than on DPW. DPW technology does not require calibration but software maintenance and hardware maintenance can be a significant part of the operating cost. The software support concerns modifications, extensions and the corresponding documentation. Initial observations would indicate DPW technologies are more expensive to run primarily due to software maintenance costs.

It is also important to take the human factor into consideration and to think about the difficulties to convert Photogrammetry operators' with experiences on analytical to such a different environment. The required training for operation and support of digital systems is quite demanding, however, the processes on analytical plotter requires well skilled operators, which require many hours of training and hence increased staffing cost. Most of the operations on AP are very labor intensive, particularly collection of height data, as each point has to be visited and measured individually. This will definitely contribute significantly to overall production costs.

At present, it can hardly be anticipated that digital systems would cost less when compared to analytical systems. The aim of digital systems is however, to extend capabilities beyond those of the analytical systems.

Hybrid system

The term hybrid here means to run a production line using analytical system for some processes and DPW for the rest of the processes or vice versa to enhance production, since this can lead to more flexible map production, reduce costs and turnaround time due to versatile data sources and process automation.

During the practicals the image point coordinates in PATB format and the GCP from the analytical plotter were exported onto the DPW. After performing IO and running the bundle block adjustment in CAPA bundle block adjustment Software the models were rectified and ready for further photogrammetric processes. Besides, it was possible to import DTM from the analytical plotter onto the DPW from which orthophoto can be produced from the analytical DTM on the DPW.

To design a production line for the best combination of tools and necessary performance parameters to achieve diversity in the production process of examples (AT parameters, DTM, feature extraction and orthophoto) one has to consider the following:

- The available equipment;
- The landscape, the possibilities to prepare control points and tie points;
- The scale of the images;
- The intended purpose, the required accuracy, the required output.
- Time
- Cost
- The experience of the operators;

Conclusion and recommendations

Conclusions

We are living in a period of very rapid technological changes. The general development, in particular electronics and computer technology, undoubtedly has opened up new advances in photogrammetry in the area of instrumentation, methodology, and integration. Currently, development in photogrammetry is concerned with the transition from analytical to DP. First applications of the new technique such as digital orthophoto, automatic DTM and automatic AT are already operational whilst the development in other areas such as feature extraction is emerging. In the past, there have been many successful introductions and changeovers of technology where the new, typically over a period of time, replaced the old. *The question now is, it is truly the case for the current move to digital?*

The project attempted to determine the efficiency and the limitations of the two systems and to investigate the possible way to integrate them to achieve diversity in the production processes (examples AT, DTM, feature extraction and orthophoto). For the whole study, the following conclusions and recommendations are made.

After the achievement of the whole study and the practical performed on the two systems, the following are the main findings, to give the answers to the research objectives and questions.

Digital systems require digital images hence to use aerial photography with high accuracy and good interpretability they must be scanned with high resolution, thus data acquisition and storage becomes more expensive. Nevertheless, if the data will be used for photogrammetric processes, where digital is superior to analytical, the time gain through automation will cancel the cost spent on scanning.

Digital photogrammetry is flexible and versatile due to the degree of automation of most of the processes. However, it was realized that stereo viewing on DPW is not as acute as in the analytical plotter environment even with imagery scanned at 24 μ m.

The time needed for the orientations on the analytical system is more than that on the digital system. Another important advantage of the digital system is that once IO is performed on an image, its parameters are included in the definition of the pixel's coordinates. This relieves the operator from re-establishing the IO in the case of re-measurement of previously used imagery. The labor time needed for digital aerial triangulation (DAT) is about 2 times less than that needed to perform the work on the analytical systems, even though the number of observations increased on the digital system. However, elapse time of DAT largely dependent on the terrain conditions, image scale and resolution. More user intervention is needed for difficult terrain types and large-scale imagery. In such a situation analytical plotter is the best system to use.

Results from the practicals indicate that the accuracy of DAT (with 24 μ m pixel size image) is at the same level as conventional analytical aerial triangulation (AAT).

The time difference for the DTM on the two systems is due to the density of buildings within the area. In such situations automatic DTM generation offer many problems, which requires extensive interactive terrain editing due to the large number of blunders in the measurements. However, in those parts where the terrain is open and less rugged automatic DTM performed very well. The accuracy of the Automatic DTM is lower than that manually collected on the analytical though they are comparable. It was realized that it is more productive to use a denser grid, in a digital environment to more accurately predict the terrain.

Feature extraction on the DPW compared to that on an analytical plotter is not very encouraging. However superimposition of vector data onto stereo view screen on a DPW is a significant advantage for map updating/revision and quality control. At present, digital orthophoto production is the only process that can be considered as fully operational in a digital photogrammetric production environment.

This study has shown that digital technologies have created new products and processes and have served to expand rather than replace the existing analytical production capability. Generally, automation is operational and makes a useful contribution to the photogrammetric process. Running both analytical and digital photogrammetry is a necessary bridge to a full digital mapping environment. Nevertheless, there is room for improvement and so the following are recommended: