ORTHOPHOTO MAPPING : A DECADE'S EXPERIENCE

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ABSTRACT

In 1968 a new national map series, the 1:10 000 orthophoto map, was started. Prior to 1978 a GIGAS ZEISS GZ1 orthophoto-projector was used for the rectification. Since 1978 a WILD OR1 orthophoto-projector has been used in an off-line mode for the rectification. Digital elevation data is acquired from stereoplotters fitted with data acquisition equipment and this data is processed in the SORA-OP program. The 1:10 000 orthophoto map is produced from 1:32 000 wide angle photography. Late in 1981 the Edition B of SORA-OP was installed and the versatility of this program led to an alternative method of producing orthophotos using 1:50 000 super-wide angle photography for the digital elevation data acquisition and 1:32 000 wide angle photography for the scanning. Panchromatic film for the orthophoto has been found to be superior in photographic quality than orthochromatic film. The great demand for these orthophoto maps has led to mountainous areas being successfully mapped. 1:50 000 orthophotos are produced from 1:150 000 super-wide angle photography for 1:50 000 revision mapping purposes.

INTRODUCTION

In 1968 the complete coverage of the 1:50 000 map was in sight and a user survey was conducted to determine the need for a larger scale map that would satisfy the requirements of planners. The result of this survey indicated a need for a map at a scale of 1:10 000 with a 5 metre contour vertical interval. After experimenting with line and orthophoto maps, it was decided to start a new map series - the 1:10 000 orthophoto map series.

The sheet lines of the 1:10 000 orthophoto maps are defined by lines of latitude and longitude with an interval of 3 minutes by 3 minutes (at these latitudes this gives a sheet size ranging from 5535 m x 5120 m in the north to 5550 m x 4620 m in the south). The reference system used is a breakdown of the reference system of the 1:50 000 map. This gives twenty five 1:10 000 orthophoto maps to each 1:50 000 map. The projection used is the Gauss Conform Projection (Transverse Mercator Projection with two degree zones) on a modified Clarke 1880 spheroid, which is the same as the 1:50 000 map and also as the national survey co-ordinate system. Man-made features that do not have a clear photographic image, certain names and the grid of the national survey co-ordinate system are annotated. Excessive annotation is avoided because of the different needs of the many specialist users of this series.

The orthophoto is rectified using 1:32 000 contact scale panchromatic photography taken with a wide angle aerial survey camera. The photography is flown along predetermined flight lines along the sheet bisector with a 90% fore- and -aft overlap. From this 90% overlap photography the photograph that best covers the sheet is selected and this ensures that every orthophoto is made from one photograph thus avoiding the problems of mosaicking.

BACKGROUND

In the earlier part of production of the 1:10 000 orthophoto map series the

complete map was done on contract by private air survey companies.

The ground control points were premarked points while the artificially marked wing/tie points were co-ordinated in an analytical block adjustment. The contours were compiled on analogue stereoplotters prior to fairdrawing the contour sheet. The orthophoto was rectified using a GIGAS-ZEISS GZ1 ortho-projector which operated on-line to a ZEISS Planimat and another GZ1 which operated on-line to a ZEISS C8. Since 1970, however, the field work and aerial triangulation has been done departmentally.

In 1971 the Directorate of Surveys and Mapping acquired a GZ1 and started producing orthophoto maps in-house. This GZ1 operated on-line to a ZEISS Planimat. In 1974 this was changed to an off-line system with the profiles being scribed onto a glass plate. With an 8 mm slit width it took approximately two and a half hours to scan an orthophoto, giving a production of two to three sheets per day. This GZ1 was used for production until mid 1981.

The initial intention was to produce these orthophoto maps as high quality printed maps, but the user preference, high printing costs, the variable demand for different maps and storage problems forced a change in policy after the experimental maps had been made. It was decided at the end of 1969 to reproduce these maps on demand using an ammonia developed diazo print.

DIFFERENTIAL RECTIFICATION METHODS

In 1978 the Directorate of Surveys and Mapping installed a WILD OR1 ortho-projector. At the same time the SORA-OP program was acquired to produce the image profiles required to operate the OR1 in an off-line mode. Installation and teething problems were experienced in the first six months, adversely affecting production.

To obtain the digital elevation data for the SORA program, four stereoplotters were fitted with locally produced data acquisition systems. Each data acquisition system consists of three rotary shaft encoders, one encoder on each of the x, y and z axes, a data logger with a keyboard, co-ordinate display and an 800 b.p.i. incremental magnetic tape deck for direct recording of an integer code and the three co-ordinates. The keyboard allows the operator to enter a code, model or point number, the option of time or distance recording mode and the recording interval.

The differential rectification of the OR1 is far superior to that of the GZ1, especially in areas of steep slopes. Initially the OR1 scanning speed was set at 20 mm per second which enables a sheet to be scanned in approximately forty minutes - nearly four times faster than the GZ1.

The off-line operating mode of the OR1 certainly has advantages over the on-line mode. A higher scanning speed can be used and more than one stereoplotter can be used to digitize the elevation data, and the SORA program can be run overnight. Working in this manner it was soon evident that more stereoplotters were required to digitize the elevation data and stereo-compile the contours. By the early part of 1980 nine stereoplotters had been equipped for digital elevation data acquisition. Today there are twelve stereoplotters equipped for this purpose. Late in 1982 a WILD BC1 analytical plotter was installed and 40% of its production time is used for contouring and digital elevation data acquisition. An advantage of the WILD BC1 is that the image profiles can be obtained directly, thereby by-passing the SORA program. This is an advantage if an orthophoto is urgently required. However the stereo-compilation of contours and the

acquisition of digital elevation data still remains a bottleneck in the production line. From time to time use has been made of contractors to do the contour compilation and digital elevation data acquisition. During a normal working day (one shift) the OR1 has a capability of scanning twelve sheets (each ± 60 cms by ± 60 cms). The area scanned is slightly larger than the orthophoto map area to allow for the registration of the orthophoto onto plotted control points and also to ensure adequate coverage of the map. Contour interpolation programs have not been considered as a means of overcoming the slow contour compilations as the computer processing time required is excessive.

The digital elevation data is acquired by digitising the contours as they are compiled using the time mode with five recordings per second, and by profiling a border area using the distance mode with a recording every 3 mm at map scale, and by recording spot heights and break lines. To increase production and accuracy WILD TA digital plotting tables have been fitted to five KERN PG2's, a WILD AG1 and a ZEISS Planicart. These tables have proved to be very successful. Drawing ink and ball-point ink pens are being used on these tables to draw the contours. This gives a neater contour sheet and also increases production time as the operator no longer has to continuously sharpen the lead.

The 1:10 000 orthophoto maps were initially planned to cover urban, peri-urban and developing areas, but the popularity of these maps has led to demands in mountainous areas. Orthophoto maps in these mountainous areas have been successfully produced using the OR1. The scanning is done using a 5 mm slit width instead of the normal 8 mm slit width and the scanning speed is reduced. On some sheets the differences in elevations exceed the range of the terrain zoom lens, but because the limitation is normally at the top end of the magnification, the basic magnification lens is set to a value higher than the setting determined by the SORA program. On some sheets small areas have been 'blurred' due to the slope exceeding the rectification capabilities of the OR1, but these areas are small enough not to detract from the value of the map. The density of the contours in these areas makes stereo-compilation of the contours a severe limiting factor in the production rate, with some sheets requiring up to seven days for the contouring. In an attempt to alleviate this drop in production and also to ensure that the contours on the orthophoto map do not obliterate the photographic background, certain orthophoto maps only have contours with a 10 metre vertical interval.

METHODS USED WITH SORA-OP (EDITION B)

At the end of 1981 the SORA-OP (Edition B) program was installed on a UNIVAC 1170 computer. The major advantage of this program over the previous version is the ability to compute a single digital elevation model (grid) from between one and one hundred photogrammetric models instead of the previous one or two models, and then obtain the necessary image profiles for a photo covering any part of that grid. The structure of the program gives the user greater flexibility in using the program.

Certain modifications have been made to this program to suit production methods. The co-ordinates of the control points can be entered directly from the final adjusted co-ordinate file of the aerial triangulation block by merely stating the aerial triangulation job file and the point numbers of the required control points. If the photo that is to be scanned has been observed in the aerial triangulation then the required image co-ordinates can be obtained from the observations made for the aerial triangulation instead of re-observing the image co-ordinates of that photo.

The versatility of the SORA-OP (Edition B) program has led to an alternate

method of orthophoto production. This alternate method involves both 1:50 000 super-wide angle and the 1:32 000 wide angle photography. The 1:50 000 photography is used to stereo-compile the contours and acquire the digital elevation data while the 1:32 000 photography is used for scanning for the orthophoto. The 1:50 000 photography is primarily used for 1:50 000 line mapping but is now serving a dual purpose.

If the aerial triangulation of the 1:50 000 photography has previously been completed, then no additional ground control point establishment or aerial triangulation is required. If the 1:50 000 mapping process has not commenced then the establishment of ground control points and the aerial triangulation are executed with the dual purpose in mind. The orthophotos are produced in blocks of sheets. Fewer photogrammetric models of the 1:50 000 super-wide angle photography than those of the 1:32 000 wide angle photography cover a block of sheets, giving a saving of between 55% and 65% in model setups. A digital elevation model is computed to cover the block of sheets and then the image profiles for each sheet are obtained.

Although the total length of contours to be compiled is the same whether using the 1:50 000 or 1:32 000 photography, a certain saving is made by contouring the larger area covered by a 1:50 000 photogrammetric model. The vertical accuracy of the 1:50 000 model is lower than that of a 1:32 000 model, but tests have shown that the vertical accuracy is still within the national map accuracy specifications. Problems have been encountered when the contouring is compiled from 1:50 000 super-wide angle photography that is a few years old, due to forested areas being cleared or trees having grown, new dams being built and new engineering and quarrying operations having been established in the interim period. In these cases the contours have to be edited.

The economy of this method is evident in the substantial saving because no field work is required for ground control and annotation, fewer photogrammetric model settings, a small saving by contouring a larger area per model and a saving in data processing time.

The example of a portion of a 1:10 000 orthophoto map shown was produced using the method described above.

PHOTOGRAPHIC AND CARTOGRAPHIC PROCESSES

The aerial film negative used is a high resolution panchromatic film and the development of the film is strictly controlled to produce the best result for orthophoto mapping. The orthophoto is scanned from a diapositive that has been exposed in contact with the aerial negative and then developed to give a range from 0,80 to 0,95. The film used for the scan diapositive is an orthochromatic film DU PONT CT7.

Prior to 1982 the film used for the orthophoto negative was also DU PONT CT7 orthochromatic film. Using this film the scanning speed of the OR1 ortho-projector was 20 mm per second. New dark rooms and photo process equipment became available during 1981 and this led to experimentation with panchromatic film for the orthophoto negative. Since 1982 AGFA P33P panchromatic film has been used. With the panchromatic film a scanning speed of 25 mm per second is used, thus increasing the production rate of the OR1. The photographic quality of the panchromatic orthophoto is certainly superior to that of the orthochromatic film.

The orthophoto negative is developed in an automatic film processor with

chemicals for continuous tone films to give a range of 1,00 to 1,25. A TIFLEX peelable film is used to mask the orthophoto negative so that only the area inside the sheet line will be reproduced.

Prior to 1978 the compiled contour sheet was exposed onto a scribe coat and then the contours, sheet lines and co-ordinate grid ticks were scribed. Using this method a preliminary orthophoto map had to be made for quality control and checking purposes. Since 1978 a continuous tone emulsion scribe coat, CONTONE, has been used. The orthophoto negative and the compiled contour sheet are registered with each other and then exposed onto the CONTONE, giving a right reading image of the positive orthophoto and negative contours. The cartographer now has the orthophoto image to assist him when scribing the contours - such as, where to stop the contours on buildings and other man-made structures and the proper turning of the contours on valley lines. Recently the scribing of the sheet lines, co-ordinate grid and grid ticks and other annotated features with digital data is being done on a WILD TA2 digital plotting table. It has been found to be more cost-effective to scribe the contours at a later stage than at the time of stereo-compilation.

The annotated names which are added to the orthophoto map, the spot heights and contour values as well as the type for the sheet surrounds are produced photographically on a phototypesetter using thin strip film. A wax-glue coating is added to the back of the strip film and then the type and annotated names are patched onto a sheet of clear film in their correct positions, giving a 'names stick-up'. A 'names' negative is made from the 'names stick-up' in a contact frame.

From the three negative elements, that is, the masked orthophoto, the scribed contour sheet and the 'names' sheet, a half tone film positive of the orthophoto map is made. This is done by a combination of exposures, firstly by screening the orthophoto using a positive magenta screen of 60 dots per centimetre with a ruling inclination of 45° and a double exposure using first a magenta filter and then a yellow filter. Secondly, the scribed contour sheet is exposed using a magenta filter, and thirdly, the 'names' sheet is exposed without a filter. All exposures are done in a contact frame using a point source of white light. From the half tone positive a master copy is made using a high speed reversal film with the emulsion down. All films are developed, fixed, washed and dried in an automatic film processor.

Ammonia developed diazo prints are made from the master copy on demand.

REVISION PROCEDURES

The greatest advantage of an orthophoto map over a line map is the ability to revise an orthophoto map more easily and quicker than a line map. At present, no fixed revision cycle for the 1:10 000 orthophoto map has been established, as the demands for coverage of new areas are still so great. However the growth of certain peri-urban and industrial areas has led to the need for second edition and in some cases even third edition orthophoto maps.

The sheets that are to be revised are first studied to determine whether any areas require to be recontoured due to human activities significantly altering the landscape. However these areas are limited and affect very few sheets. For the orthophotos that were produced on the GZ1, no digital elevation data exists and these sheets are profiled with profile lines being

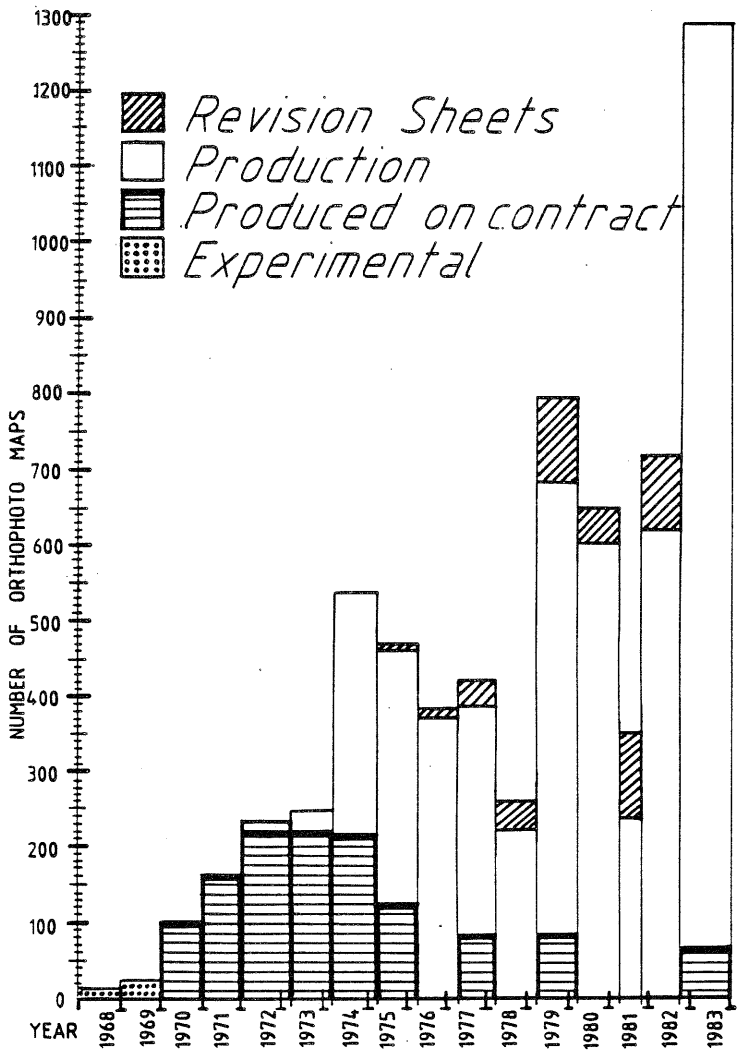
5 mm apart at map scale and approximately parallel to each other. For orthophotos that are produced on the OR1 the digital elevation model is archived onto magnetic tape and is used again for the revision, so that for these sheets no stereoplotter work is required and only the image profiles need to be computed. From this a new orthophoto negative is produced.

A positive print on bromide paper is made from a combination of the new orthophoto negative, the existing contour sheet and the existing 'names' sheets. This bromide is used to annotate changes to the 'names' sheet and any contours that might be affected by new development. Because of the limited annotation on the orthophoto maps, only a few changes are normally required. If necessary, the contour sheet can be revised using REPRO-SCRIBE material. The 'names' sheet is revised by 'duffing' out those names that are incorrect or no longer appropriate and then making a film positive on which the names to be added are patched. A new 'names' negative is then made.

The new orthophoto map is made using the new orthophoto negative, contour sheet and 'names' sheet.

PRODUCTION

The production rate of the 1:10 000 orthophoto maps has increased with time as more equipment has become available and new production methods have been introduced. The bar chart below shows the production figures for the 1:10 000 orthophoto maps with divisions for sheets produced on contract by private air survey companies, revised sheets and sheets produced in-house.



Points to note from the bar chart are :-

* 36 experimental sheets were produced in 1968 and 1969.
* In the period April 1974 to March 1975 the change to an off-line system for the GZ1 led to increased production.
* In the period April 1978 to March 1979 the OR1 was installed but installation and teething problems caused a drop in production.
* In the period April 1979 to March 1980 the carry over from the previous year and also more streamlined methods led to increased production.
* In the period April 1981 to September 1981 the production figures are for a six month period only. Also during this period production was affected by a move to new premises and all the equipment was given a major service.

It is hoped to maintain an annual production figure of one thousand sheets.

Besides the production of 1:10 000 orthophoto maps, 1:50 000 orthophotos are made from 1:150 000 super-wide angle photography. The 1:50 000 orthophotos are used for revision of 1:50 000 line maps. This procedure has certainly had a profound effect on the revision of line maps. A number of miscellaneous orthophoto maps at various scales for special project mapping are also produced.

CONCLUSION

The Directorate of Surveys and Mapping in South Africa has changed its production methods of orthophoto mapping over the years and continues to study methods for improving both the quality and the production of the orthophoto maps.

Many people have been sceptical about the need and usefulness of orthophoto maps. The great demands for the 1:10 000 orthophoto map must surely be an indication of the need and usefulness of these orthophoto maps.

REFERENCE

Lester K J "Orthophoto Mapping in South Africa" Proceeding of Fifth Conference of Southern African Surveyors, Salisbury 1974.

* Any use of trade names and trademarks in this paper is for identification purposes only and does not necessarily constitute endorsement by the Directorate of Surveys and Mapping.

Portion of South Africa 1:10 000 Orthophoto Map