DEVELOPMENT OF DIGITAL ORTHOPHOTO MAPPING

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KEY WORDS: Orthoimage, Rectification, Mosaic, Scanner, Digitization, Softcopy, Production.

ABSTRACT

As Computers become more and more powerful, mapping tools for the 21st century are undergoing tremendous changes. With the benefit of today's computer technology, digital photogrammetry is replacing traditional analytical means as softcopy photogrammetric workstations become more and more commercially available in the surveying and mapping industries. The major features of the workstations are the use of digital images and the performance of mathematical modelling by automated computations in photogrammetric applications. With this tool non-photogrammetrists can also do photogrammetric work efficiently. Softcopy photogrammetry can now perform most photogrammetric tasks at a throughput and accuracy either better or at least equal to traditional analytical tools and its potential is unlimited.

Time Aerial Surveys Company (TASC) has recently completed two (2) projects using these new technologies. One project was to produce fifty (50) basemaps in digital orthophoto format for the City of Tai-Chung while the other was to produce color orthophoto maps of Tai-Chung Harbor. Both projects, involved the latest digital photogrammetric technique, are the first of its kind in Taiwan.

This paper describes the entire digital photogrammetry workflow from image scanning to data compression to DTM/feature extraction to orthophoto production. This paper also highlights the challenges that TASC has faced as to how the best results could be achieved economically with limited resources.

INTRODUCTION

In the past forty (40) years, the development of photogrammetry has gone through rapid changes from ancient analog mapping tools to modern analytical stereoplotters, and to today's digital photogrammetric workstations. In 1995, Time Aerial Surveys Company successfully completed two (2) orthophoto mapping projects, both in digital format, using these new technologies. One project was to produce fifty (50) black-and-white (B&W) photo basemaps covering the 350 km^2 of the City of Tai-Chung while the other was to produce color photo maps covering the 160 km^2 of Tai-Chung Harbor. Both projects, involved the latest digital photogrammetric technique, are the first of its kind in Taiwan. The workflow starts from image scanning of aerial photos, to aerotriangulation, to digital terrain model (DTM) data recording, to orthophoto rectifications. The state-of-the-art facilities employed by TASC include 1) Intergraph-Zeiss PS1 scanner for image scanning at a resolution of 22.5 μm; 2) Intergraph InterMap 6887 ImageStation for aerotriangulation, DTM generation and orthophoto rectification; 3) Filmrecorder for orthophoto map production.

Although both projects are using the latest digital photogrammetric technique, their workflows are somewhat different. This is primarily attributed to the different requirements of black-and-white versus color and the superimposition of topographic linemap over photo images.

Project I - Basemaps

The first project, sponsored by the Ministry of Interior, calls for a production of fifty digital orthophoto basemaps at 1:5000 scale covering the entire metropolitan area of the City of Tai-Chung. Funds were granted for implementing this project on a pilot basis due to a transition from the traditional analog to digital orthophotos.

Background. Originally, a total of 3,773 photo basemaps covering the 35,981 km^2 of the entire island of Taiwan were established over a seven year period since 1975. Of which, 3209 maps are in 1:5000 scale for areas with elevations below 1,000 m while the rest 564 maps are in 1:10000 scale for mountainous areas with elevations above 1,000 m. These maps are being updated every five years using analog means until now. The orthophoto basemap program is the responsibility of the Ministry of Interior. The next five-year plan of updating the basemaps will be switching to the digital format. Due to rapid urban development in recent years, priority for updating will be given to the 1:5000 scale maps first.

Basemap Productions. On this project, aerial photos taken at 1:18000 scale are having an end lap of 80 percent to allow for the possibility of selecting one photo covering one complete map quadrangle. Consequently, it allowed one photo making one map and no photo mosaic was required. The approach of one photo making one map has always been the standard practice for producing photomaps in Taiwan. In light of such requirement, aerial photos were taken with flight lines oriented north and south along the centerline of map quadrangles. Although it requires larger end laps (e.g., 80-90 percent as opposed to the typical 60 percent), the added costs are easily outweighed by the savings from no mosaicking.

Aerial photo films were scanned at 22.5 μm, a resolution deemed optimum based on a technical evaluation and backed by experiment. It should be pointed out that such resolution is applicable only when Intergraph-Zeiss PhotoScan PS1 is being used as this resolution is a multiplier of 7.5 μm. When other comparable scanners such as Lecia DSW 200 or Vexcel VX3000 Plus are used, a resolution in the range of 20-25 μm may be appropriate. At 22.5 μm, it offers 4/10 meter pixel resolution and requires approximately 100 megabytes (Mbytes) of data storage for each image. From a practical standpoint of view, file size of this order of magnitude is still manageable when considering large volume productions. The 1.3 GB optical disk cartridges were used for data storage of the scanned images. However, the 8mm magnetic tape could have been an option but was not used in daily operations due to its slow speed of data retrieval.

A number of various types of large data storage media are available in today's market. For example, there are magnetic tapes such as the 8mm Exabyte tape, the 4mm DAT tape and the 9-track tape, etc., and the Magneto-Opticals (MOs) such as the 5.25" optical disk cartridge, just to name a few. In general, magnetic tapes are relatively inexpensive and are good media for archives. However, they are slow in data retrieval and may not be effective in the day-to-day operations in a production environment. The use of optical disks provides an effective means for quick data retrieval instead.

Map grids are based on Transverse Mercator Projection with two (2) degrees wide zone instead of the six (6) degrees for UTM. It should be pointed out that map projection with a two-degree wide zone is unique to Taiwan.

Information regarding magnetic declinations was obtained from the U.S. Geological Survey (USGS) via on-line information system. The International Geodetic Reference Field (IGRF90), a geomagnetic field mathematical model, covering the worldwide regions with date range from 1945 to 1995 was chosen for Taiwan. The IGRF90 model shows that Tai-Chung had a magnetic declination of about 3°07' W in 1995 and an average annual change of approximately 1.2 min westerly.

Aerotriangulation was measured on Zeiss P-2 stereoplotter using PAT-M for block adjustment. A total of 4208 photogrammetric pass points were measured which yielded a sigma naught of 6.7 μm for horizontal block and 10.8 μm for vertical block, respectively. Aerotriangulation of this accuracy is well within the 18 μm tolerance, a condition required for meeting the contract.

Contour lines on mountainous areas were generated automatically from Intergraph ImageStation while contours in relatively flat terrain were manually plotted from Zeiss P-2 and P-33 stereoplotters, respectively. In light of the fact that images are representing only the tree tops, manual adjustment of tree heights has to be taken into consideration when contour data are generated automatically from ImageStation. A 5-meter contour interval was used. The DTM was then derived by interpolation from contour data coupled with breaklines and spot elevations at 20-meter center, a density equivalent to 4mm at the map scale. The DTM was recorded and saved in ASCII format for general applications.

Rectification. With respect to the orthorectification, the DTM was generated automatically from Intergraph ImageStation at 9-meter center, a density deemed necessary for the best results of rectification. The data was used as an input to ImageStation for orthophoto rectification. It should be noted that tree top elevations are the basis for rectification of the images. Storage of data before and after rectification was on 1.3 GB optical disks.

The linework including ground features such as roads, rivers, contour lines, text and map symbols was digitized in AutoCAD and subsequently converted to Microstation DGN. The vector was then rasterized in order to overlay with photo images. In the past, to add topographic line map onto orthophoto would require multiple sheets of film negatives for printing. Not only does it add costs to the reproduction, but also invites mistakes due to possible human errors. Through the use of the sophisticated Map Publisher, photo images along with the rasterized topographic linework were output to a single TIFF (Tagged Image File Format) file per map for a filmwriter production. This would eliminate possible misalignment of multiple sheets due to an operator error. The Map Publisher does the necessary work including mask, fill, alignment, cut and paste, all in one single softcopy process.

Outputs. Screen SG-618A, a high end filmrecorder, was used for generating the film negatives. To prepare for an output plotting of orthophotos, files were saved in TIFF format and then exported from UNIX workstation to PC via PC/TCP(Transmission Control Protocol) network. Through the use of Photoshop, the orthophoto image was checked for quality and edited as needed for final hardcopy output with a film writer.

In addition to hardcopy orthophotos, softcopy output is also in high demand and offers a wide range of applications. The softcopy orthophotos can be used in conjunction with the geographic information systems (GIS). However, often time data transfer may become an issue when original files being transferred are not compatible with the new system. This is due to a number of different file formats being available in the industry. For image processing, the most commonly used ones are Binary, TIFF, PostScript, COT (Continuous Tone), and etc. It is prudent that the suppliers to ensure that file format as well as the storage media be compatible with the user's system to avoid unnecessary problems.

Project II - Color Orthophotos

The second project calls for a production of color orthophoto maps of Tai-Chung Harbor in 1:10000 scale. In addition, line topographic maps of 1:5000 and 1:10000 scale were also included in this project. The workflow is similar to the ones described above with the exception of mosaic and larger file sizes due to color input and output. Besides larger file sizes, the whole process tends to be very time consuming as a result of the 3-band (RGB) scanning as well as the four-color (CYMK) separations for hardcopy production. Softcopy mosaic was performed to achieve seamless results with a good success.

On this project, aerial photos were taken at 1:20000 scale using Kodak Aerochrome MS 2448 color aerial film. With respect to aerial photography, the decision to fly or not to fly as restricted by weather conditions was quite a challenge. Besides strict weather conditions typically needed for aerial photography, optimum timing according to low tidal schedule was an important consideration required by the contract. To meet such requirements, the window of opportunity for aerial photography became so narrow that it took approximately two (2) months before a successful flight was made.

Aerial photo films were scanned at 22.5μm resolution on three red, green, blue (RGB) files. Scanning time and file sizes required for each photo became tripled the ones normally required for black and white. Therefore, it is critical that data storage be optimized for large volume productions.

Aerotriangulation was performed on Intergraph IM 6887 softcopy stereoplotter using PAT-M adjustment. A total of 440 photogrammetric pass points were measured and recorded which yielded a sigma naught of 8 μm for horizontal block and 14 μm for vertical block, respectively.

The workflow is similar to the ones required for the basemaps with the exception of no superimposition of topographic linework over the images. Unlike the basemaps, mosaic was needed to form a complete orthophoto map. In addition, the images were rectified individually for the respective RGB bands. Through the use of Map Publisher, color photo images were segregated in a 4-color (CYMK) separation and then output to a TIFF file for a filmwriter production.

To prepare for an output plotting of color orthophotos, digital files in four-color-separations were saved in TIFF format. Through the use of Intergraph ImageStation and Photoshop, the operator was able to perform softcopy mosaic and match color tones as necessary. For mosaicking, the orthophoto is digitally processed to remove seam lines between the mosaicked images. Mosaics with seamless results were achieved with ease due to today's softcopy technology.

ACCURACY

Editing was made during every stage of map compilation. A minimum of ten (10) percent of map quadrangles produced was field checked for accuracy with precise traverse survey on prominent ground features. The results of field check are listed in Table I.

Measures of Precision. In accordance with the contract agreement, at least 90 percent of all points checked shall meet or exceed the following acceptance criteria.

- Discrepancy of coordinates of control points between that of the maps and field surveys shall not exceed 0.2 mm.
- Discrepancy of coordinates of prominent ground feature between that of the maps and field surveys shall not exceed 0.4 mm.
- Discrepancy of spot elevations between that of the maps and field surveys shall not exceed 1/4 of the contour intervals.
- Discrepancy of contour lines between that of the maps and field surveys shall not exceed 1/2 of the contour intervals.
- In forestry area where it is normally covered with dense trees, interpretation of ground elevations is difficult. Discrepancy of contours between that of the maps and field surveys is in direct proportion to the tree heights. In this case, such discrepancy shall not exceed 1/2 of the tree heights.

On both projects, all points being checked met or exceeded the guidelines stated above. As it can be seen from Table I, the results of field check are well within the allowable discrepancies.

DATA STORAGE

Storage of data in the day-to-day operations was on 1.3 GB optical disks. A 22.5 μm scanned image file is approximately 100 Mbytes for each photograph. Data was compressed to 1/3 of their uncompressed size using the JPEG (Joint Photographic Experts Group) compression. Further compression to smaller file sizes was not considered. The rule of thumb is that geometric distortion for compression ratios below 5 can be neglected. Data was uncompressed before rectification and then compressed again after rectification of the images.

Storage of digital orthophotos for the entire island of Taiwan would require at least 350 optical disks. The same data could be stored on eighty (80) 8mm Exabyte tapes. For archives, the latter would be a good choice.

CONCLUSION

In conclusion, softcopy photogrammetry can now perform most photogrammetric tasks at a throughput and accuracy better than traditional mapping tools and its potential is unlimited.

Like all mapping projects, digital orthophotos are complex and evolving. Through the use of the latest digital photogrammetric technique, both projects were successfully completed with excellent results. This has definitely set a milestone for promoting digital orthophotos in Taiwan.

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Table I

Accuracy: Editing was made during every stage of map production. A minimum of ten (10) percent of map quadrangles produced was field checked for accuracy with precise traverse survey on prominent ground features. The results of field check are list below.

1) Photo Basemaps of Tai-Chung City

Map scale:	1:5,000
Number of map quadrangles produced:	50 maps
Number of map quadrangles field checked:	5 maps
Number of ground features field checked:	15 points

Discrepancies of horizontal coordinates and elevations of ground features between that of the maps and field surveys:

	X variance	Y variance	Z variance
Maximum	12.2 cm	11.7 cm	18.5 cm
Minimum	0.3 cm	0.2 cm	0.3 cm
Average	6.3 cm	6.0 cm	9.4 cm

2) Orthophoto of Tai-Chung Harbor

Map scale:	1:10,000
Number of map quadrangles produced:	16 maps
Number of map quadrangles field checked:	5 maps
Number of ground features field checked:	18 points

Discrepancies of horizontal coordinates and elevations of ground features between that of the maps and field surveys:

	X variance	Y variance	Z variance
Maximum	57.2 cm	58.9 cm	48.8 cm
Minimum	0.9 cm	2.3 cm	6.4 cm
Average	29.0 cm	30.6 cm	27.6 cm