Innovation in Aerial Triangulation

Toya Nath Baral
Chief Survey Department
Survey Department

INTRODUCTION

Photogrammetry is still u ndergoing a phase of change. The challenge consists not only in the allround transition to digital photogrammetry, but also in the transition to second-generation digital photogrammetric Workstation (DPWS) as an end to end, workflow oriented solution. Different data sources such as GIS databases or various sensor data must jointly be processed in the future (DOrstel, 1999).

AAT has earned itself a place within the DPWS chain. The former operating principle which has the primary function of controlling the measuring process does only play a seconda ry role these days. The demand for fa st data validation, self-checking mechanisms and a block-wide, end product-oriented approach does have a c onsiderable impact on t he importance of AAT. The new generation of DPWS is characterized by the addition of further data sources such as GPS/fNS measurements and the output of improved high quality orientation data.

As summarized by Tang (Tang, 1999) a n ew AAT approach must incorporate m ethods for efficient blunder detection and elimination, increase the number of multi-ray points, ensure an even point distribution, include techniques to process poorly textured areas, and provide users with an i ntuitive and in structive interface for handling cases of a utomation failure.

Innovative technologies like GPS/INS are more and m ore challenging the business of aerial triang ulation, and thus compete with the next generation of AAT systems (Cramer, 1999). Although the determination of the exterior orientation parameters by the GPS/INS syste ms has been improved significantly, the accuracy of these parameters is still not good enough for standard photogrammetric applications. Therefore, the integration of self calibrating block adjustment (Ebner 1976) to compensate for systematic image errors based on available tie points and a c ombined block adjustment computing for shift and drift parameters must be implemented.

This paper concentrates on some main aspects of g enerating high-quality exterior orientation data within the new ImageStation Automatic Aerial Triangulation System (ISAT) only. A More comprehensive description on the complete workflow of (ISAT) is given by Madani (Madani et al., 2001).

NEW IMAGESTATION AERIAL TRIANGULATION

The principle of the PHODIS digital AAT procedure is to generate a dense cl oud of tie points well distributed over the entire block only. An external Bundle Block Adjustment program (BBA) is then called to detect and eliminate blunders in the measurements and finally determine image exterior orientation parameters. This working strategy was based on the fact that BBA programs have been used in the photograrnmetric practice since long. However, it requires advance techniques of blunder detection inside the BBA programs. On the other hand, it st ill need to get the entire system performance optimized.

To work based on very roughly known input data of exterior orientation is another significant feature of the PHODIS AT system, which has been proven to be advantageous for many years. With the increasing GPS/INS application for imaging flights today, an optimum integration of high quality exterior orientation data delivered by GPS/INS systems, such as the POS Z/I 510 system, is implemented in the new AAT system. In this case, a complete AAT is not necessary, since only few points are sufficient for system calibration and quality control of direct measured EO parameters. Here, the user expects that the automatic procedure can make use of the high quality orientation input to reduce the processing time to a very limit.
Considering this, it is obvious that a fundamental change in the implemented AAT approach needs to take place. In the new ISAT solution the following main features were added:

- High quality tie points by integrated free net adjustment
- Detection of geometrically weak area.
- Optimized processing in case of precise EO
- Computation of exterior orientation (EO) shift and drift parameters during BBA.

High Quality tie points

To generate a set of high quality tie points out of the extracted point measurements a robust free net adjustment is introduced. The bundle block adjustment takes place at intermediate pyramid levels, each time after extracting tie points. As results, blunders are eliminated from the measurements on one hand, line improved EO parameters of each image are obtained and can be used late to track down identified features more precisely on the other.

Based on the tie points, a-priori project wide standard deviation, given EO parameters and corresponding standard deviations, the least squares adjustment is started. Residuals of the observations are forwarded to the implemented weighting function, and new weights are computed and assigned to the observations for the next iteration. If the weight of an observation is smaller than a predefined threshold, the corresponding photo point can be marked as a blunder. The task of a weighting function is to generate large weights for good observations (small residuals) and small weights for bad observations (large residuals). ISAT uses the Danish Method (Kubik et al., 1987) for robust estimation. Alternatively, the well known Stuttgart method can be used. The robust adjustment is internally repeated until no more points can be removed, or a predefined threshold is reached.

After finishing BBA at the intermediate level, a consistent and reliable set of image coordinates is available. This set of image coordinates is essential for the weak area detection.

Detection of geometrically weak areas

One of the major tasks of the embedded BBA is to detect the geometrically weak areas over a photogrammetric block to manage the internal matching strategy and to tag those areas for operator interaction.

In order to tag geometrically weak areas the image area is subdivided into a regular 3x3 grid (see figure1). Each grid mesh represents a von Gruber area, where the availability of tie points is a prerequisite for a stable geometric block connection. Detected tie points in each of those grid meshes can now be investigated by several criteria. As a pre-knowledge an expected overlapping level for each mesh can be defined.

The criteria to evaluate weak areas are

- The tie point quality derived from the point residual provided by BBA
- The number of multi-ray points in the grid mesh.

If points in a mess are not able to deliver a sufficiently accurate solution for the final BBA the mesh area is tagged as a weak area.

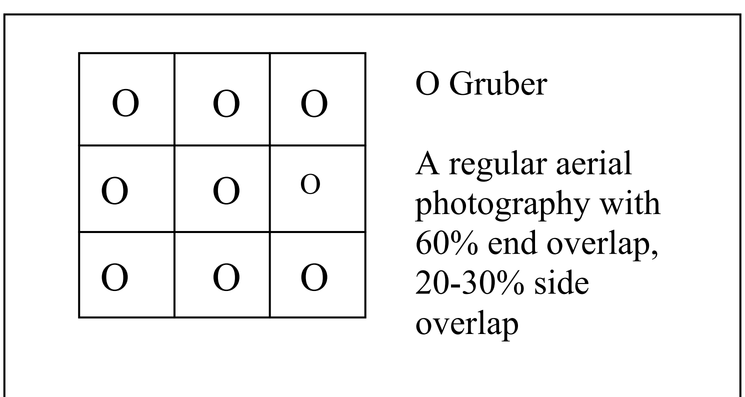

Figure 1: 3*3 regular grid

Weak area information is passed to the matching kernel to control point extraction. The paramount goal of this processing step is to close as many weak areas as possible by automatically searching for tie points in multiply overlapping areas. Hereby points with high connectivity are preferred.

This processing part is one of the most important steps to output a tie point list which has well distributed, highly connected points without blunders.

As the automatically generated point list may contain weak areas, especially in poor textured image parts Image Station offers a semi-automatic procedure to measure points in those areas. This function guides the user to the detected weak areas, opens all involved images and offers semiautomatic point measurement functions to insert tie points into weak areas.

Optimized processing in case of precise EO

Having just roughly known EO parameters available the AAT approach starts with a block formation based on feature-based matching (FBM) and automatic relative orientation at the start level (see figure 2), and runs through the intermediate level to generate a primary point list. This step serves to connect the whole image block and to deliver relative EO parameters for each image. In case of available GPS/INS EO, because of the good geometric determinability, the block formation step must not be preferred. In this case the tie point list can be generated forming the block directly at the intermediate pyramid level.
As a consequence matching can be started directly from the intermediate level and focused on multiply overlapping areas which can be defined precisely.
Based on the precise EO the forward intersection can deliver the most reliable check on blunders in the tie point list and thus guarantees a high quality of the remaining points. Furthermore, based on the good quality of tie points, the point tracking based on least squares matching (LSM) can work faster than that in the general case because well-qualified input points improve the success rate of the matching as well.

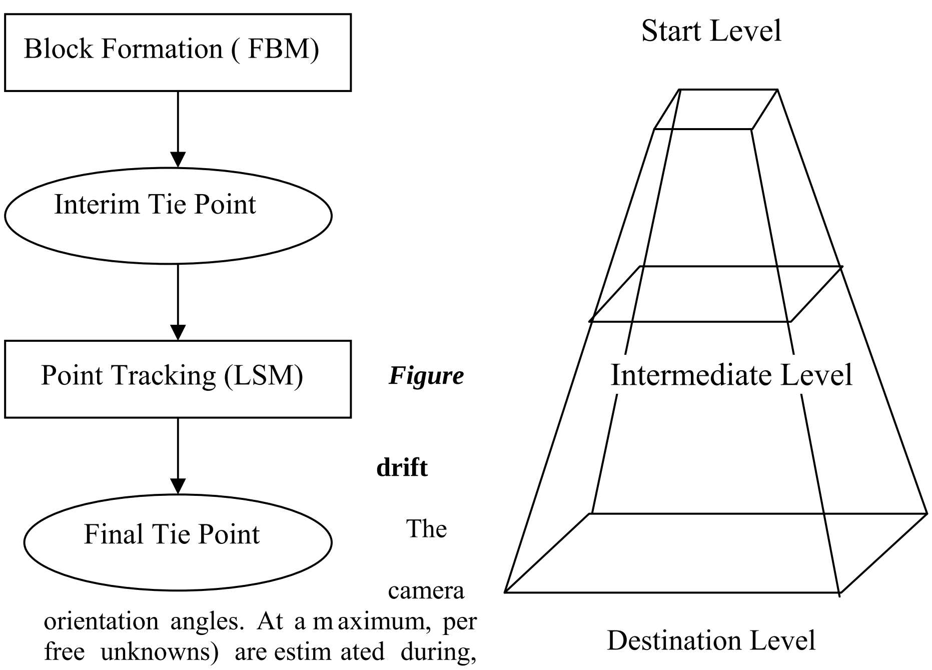

Figure 2: Structure of'AA T

Computation of EO shift and drift parameters during BBA

The exterior orientation shift and drift corrections are applied to the 3 camera positions as well as to the 3 orientation angles. At a maximum, per strip 12 additional parameters (as free unknowns) are estimated during the bundle block adjustment. Then they are applied to the EO parameters (see figure 3). These parameters are normally used during aerial triangulation process only. For subsequent applications, the corrected EO parameters in the final Project Coordinate System (X_o, Y_o, Z_o, ω_o, φ_o, and κ_o) are exported.

The weights for the given exterior orientation parameters are either derived from the GPS/INS post processing software or are estimated by the user. If no observations for the parameters are provided, the approximate values will be zero. If some photos do not have GPS and/or INS information, their EO parameters will be estimated during BBA.

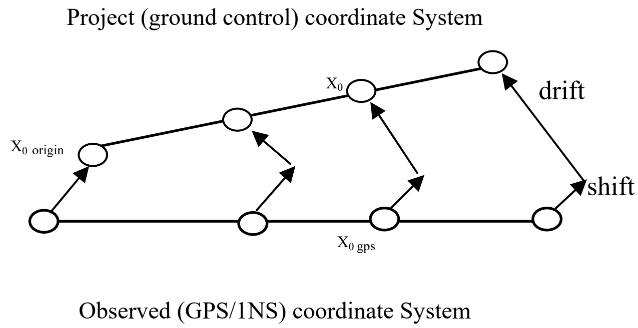

Figure 3: EO corrected by shift and drift parameter

CONCLUSION

The introduced Image Station Ae rial Triangulation package replaces the former MATCH AT based triangulation package. The ISAT product delivers fully automatically determined homogenous, well-distributed and best-matched multi-ray tie p oints. This is achieved by a b uilt-in robust bundle block adjustment during all phases of the image matching operation. The embedded robust bundle block adjustment is performed in a sense o f free net adjustment. The bundle block adjustment is improved to optionally compute sensor self calibration as well as sh ift and drift parameters. ISAT is provided with improved search algorithms to find sufficient and well-distributed tie p oints in the overlapping regions. An efficient blunder detection and a well-thought weak area handling serve for an optimized workflow. Input of EO information delivered by GPS/INS sensors is used to reduce the processing time and allows ISAT to be used as an efficient validation tool as well.

REFERENCES

Week '99, Fritsch D., Spiller R. (Eds.), Heidelberg, 59-70.

Cramer M. (1999): Direct Geocoding - Is Aerial Triangulation Obsolete? Photogrammetric

Dorstel C. (1999): Perspectives for aerial triangulation offered by Z/I Imaging. Photogrammetric Week'99, Fritsch D., Spiller R. (Eds.), Heidelberg, 205-210,

Ebner H. (1976): Self-Calibrating Block Adjustment. Bildmessung und Luftbildwesen 44, 128-139.

Kubik, K., Merchant D., Schenk T. (1987): Robust Estimation in Photogrammetry. Photo grammetric Engineering and Remote Sensing (53) 2, 167-169.

Madan, M., Dorstel, C., Zeitler, W., Tang, L. (2001): Z/1 Imaging New Automatic Aerial Triangulation System. ASPRS 2001 , St. Louis, USA, Mai 21-24, 2001.