MATCH-AT: Recent Developments and Performance

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ABSTRACT

Since 1996 INPHO offers the product MATCH-AT for automatic digital aerial triangulation. Its modern concept with integrated bundle block adjustment and blunder detection proved to be a good basis for an almost complete automation of aerial triangulation. New technologic requirements and user demands motivated INPHO to develop several new features, such as GPS/INS handling, stereoscopic point measurement, sub-block handling, graphical analysis of the results, a full integration of MATCH-AT into INPHO's photogrammetric system, and additional data formats for the exchange of image orientation data. This development resulted in the most advanced MATCH-AT version 3.0. INPHO's new multi-sensor block adjustment software inBLOCK will bring MATCH-AT again to a new level of performance of digital aerial triangulation.

1. INTRODUCTION

The first products for automated digital aerial triangulation were presented in 1996. Some of them were primarily automatic point transfer systems (Braun et al, 1996, Miller et al, 1996), needing an external block adjustment and blunder detection. INPHO's MATCH-AT (Krzystek et al, 1995, Heuchel et al, 1996, Ackermann, 1996) was the first product automating the full aerial triangulation process.

Within a short period, automated aerial triangulation was widely used in photogrammetric production, because of its enormous economic advantage compared to conventional aerial triangulation. As an example, the 1722 images block Baltimore County (Heuchel et al, 1998) could be processed with MATCH-AT by one operator in about two months, instead of about six months with manual block preparation, point transfer, measurement and block adjustment.

Another main benefit of the automated method is its superior accuracy. MATCH-AT's point measurement by least-squares matching results in excellent sigma naught values of 0,15 to 0,25 pixels. A pixel size of about 20 micron is sufficient for sigma naught values of 4 to 5 microns. Typical sigma naught values of conventional aerial triangulation are between 5 and 8 micron.

An international test of OEEPE and ISPRS (Heipke et al, 1998) showed the potential of automated aerial triangulation, but also some shortcomings of the new methods. Completeness of point transfer and quality of the tie points had to be improved. Too many tie points were measured in two or three images only. In addition, better analysis tools for the results were demanded.

INPHO accepted this challenge and improved MATCH-AT in several steps, resulting in the new version 3.0.

2. CONCEPT OF AUTOMATIC AERIAL TRIANGULATION WITH MATCH-AT

From the beginning, MATCH-AT has combined the full aerial triangulation in one automatic process, including point selection, point transfer and block adjustment. It starts from scratch by using only little initial block information, such as interactively measured control points and initial values for the projection centers.

The key idea has been to use an integrated block adjustment in order to achieve a fully automated process. The internal block adjustment is not only applied to the final adjustment, but in all stages of the process, its robust adjustment capabilities are used for the detection of outliers and for the initialization of the subsequent steps. A separate block adjustment program is not needed.

GPS-derived exposure positions are used in the block adjustment, including shift and linear drift parameters. A DTM may be used for an improved block initialization. Self-calibration and flexible weighting of the observations are available like in advanced conventional block adjustment products.
The MATCH-AT process applies image pyramids for a coarse-to-fine strategy. In each pyramid level the following steps are performed:

- Automatic initialization of the tie point areas. Tie points are preferably selected at the von Gruber positions where the best multi-image tie points are located.
- Feature extraction using the Förstner operator,
- Preliminary image matching using a combination of feature-based and least-squares matching, and a sophisticated strategy for obtaining evenly distributed tie points over the whole block.
- Robust bundle block adjustment for automatic tie point selection and for the initialization of the next pyramid level.
- In the last pyramid level the internal block adjustment supplies the final adjustment result.

In weak block areas tie points can be added by interactive point measurement. After manual adding of points, the internal block adjustment can be started again, without repeating the automatic process.
Large blocks of about 2000 images were processed with MATCH-AT without subdivision. The computing time per image is only in the range of one to two minutes, including all steps from block initialization to final block adjustment.

3. NEW DEVELOPMENT FOR MATCH-AT 3.0

Several important new features of MATCH-AT were announced at the 19th ISPRS Congress in Amsterdam in July 2000. They were made available to the users of the new MATCH-AT version 3.0 at the end of 2000:

3.1. GPS/INS Handling

The use of GPS derived antenna positions during photo flights has considerably improved the performance of the aerial triangulation process. It mainly helped to reduce the amount of necessary ground control points. GPS-supported aerial triangulation with shift and drift parameters for the GPS trajectory has been a feature of MATCH-AT from the beginning on.
Now that IMU (Inertial Measurement Unit) technology has evolved, it is expected that the photogrammetric community will increasingly use the data in combination with GPS in softcopy systems (Cramer, 1997, Heuchel, 2001). MATCH-AT 3.0 is able to consider INS data as additional observations. The data formats of Applanix POSEO and IGI Aerocontrol are directly supported. Offset and drift parameters can also be applied to the data obtained from GPS/INS.
The use of GPS/INS data in an automated aerial triangulation system can

- support the aerial triangulation process by providing highly accurate exterior orientation parameters from the beginning, simplifying the point measurement process of automatic aerial triangulation, and improving the quality and reliability of the orientation results,
- help to install an on-flight camera calibration for the focal length and principle point displacement,
- reduce the number of necessary tie points and of tie point areas,
- help to do aerial triangulation without cross-strips.

In the process of direct geo-referencing, an automatic GPS/INS-supported aerial triangulation is a mandatory step to check for gross errors and statistical properties. Without an aerial triangulation being included, direct geo-referencing would be non-redundant, and therefore contradictory to one of the main rules of surveying, which is to implement methods for the control of observations.

3.2. Stereo Measurement of control points and tie points

Stereoscopic point measurement is known to support the point identification process significantly. In particular the measurement of non-signalized control points can be improved considerably.
MATCH-AT 3.0 is available with an optional stereo module. It works in a stereo comparator mode with a standard mouse and keyboard. The stereoscopic display is in non-interlaced mode with stereo-in-a-window techniques based on standard PC hardware and software (OpenGL). Passive or active stereo viewing systems may be used in combination with different graphics adapters (3DLabs Oxygen GVX and others) which are available for one- or two-monitor stations. Stereoscopic image viewing and image movement are of highest quality.

3.3. Graphical Analysis of MATCH-AT Results

inSPECT, the new MATCH-AT tool for graphical analysis of aerial triangulation results is an important new module of MATCH-AT. Although blunders are automatically eliminated by the internal robust block adjustment, the operator will have to check the results for weak block areas with insufficient accuracy or incomplete image connections. It is much easier for the user to do these checks graphically rather than looking into long lists of statistical results.
inSPECT represents MATCH-AT results in form of complete block overviews or views of any block parts. A most efficient check is possible by showing all image connections. The user can easily detect holes in the triangulation network. In addition, it is possible to show residuals and error ellipses.

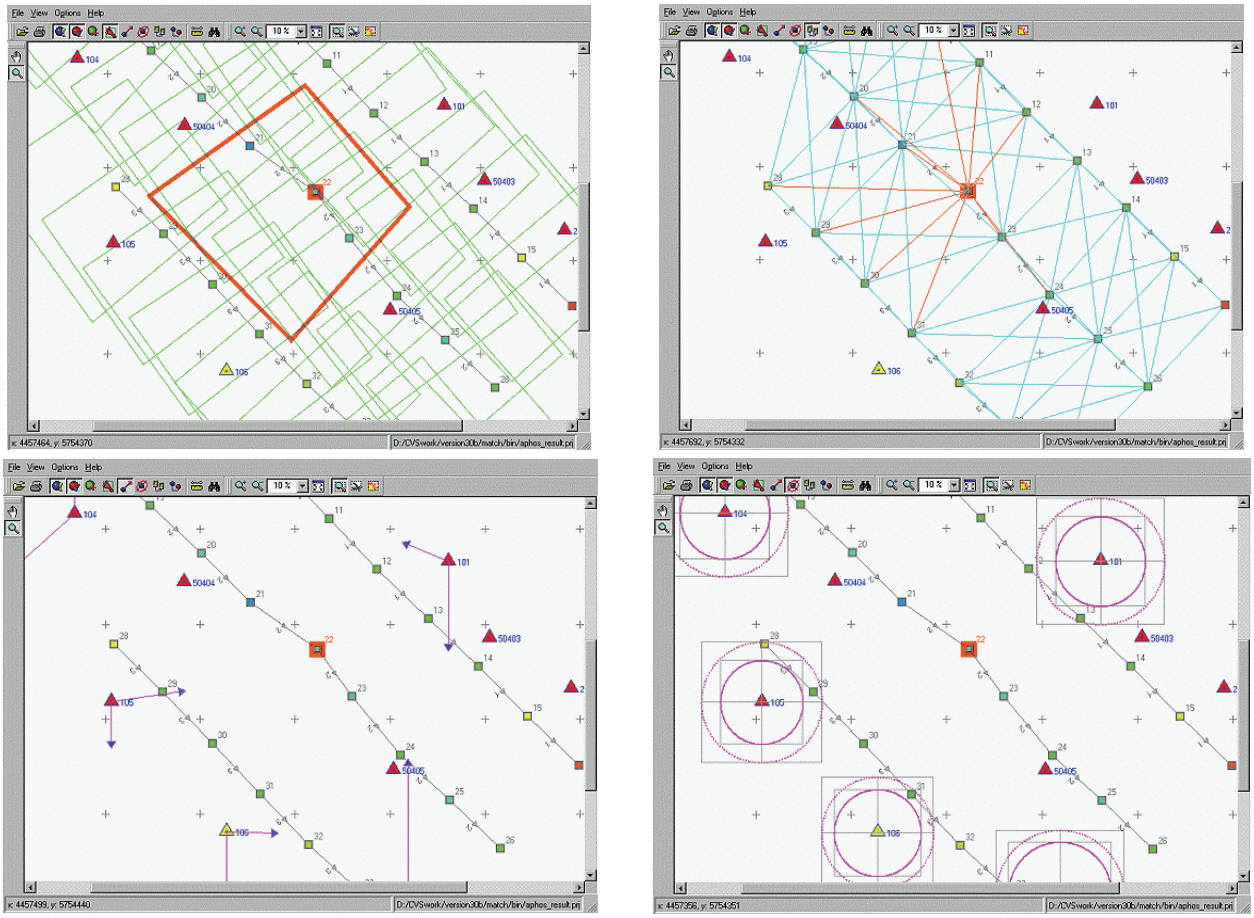

Figure 1: Examples of graphical block analysis with MATCH-AT

3.4. Sub-block Handling

In very large aerial triangulation projects of 1.000 images and more, a subdivision of the block offers organizational advantages:

- Aerial triangulation can start before all images of the block are scanned. For large blocks the scanning process can take several weeks.
- During interactive quality control, blocks of several hundred images can easily be handled. Although today's computer technology allows to manage and visualize very large blocks, it is getting difficult for the operator to keep the overview.

Therefore INPHO decided to develop the organizational tools for the handling of sub-blocks. The user may subdivide a block into parts of any size. The sub-blocks need to have an appropriate overlap of at least one stereo model and one strip.
Each sub-block is handled like a full block. The internal block adjustment for sub-blocks does not require any control points. This is important for a flexible subdivision of blocks. Internally, all sub-blocks are automatically merged into one single block, and - as a final step - adjusted by the internal block adjustment tool, using robust and least-squares adjustment steps.

3.5. Export of Orientation Data for other Systems

Aerial triangulation is often performed as a separate project for data capture at other locations. Therefore, a variety of export formats are needed for transferring the MATCH-AT orientation data to other photogrammetric systems. MATCH-AT supports the following formats:

- MATCH-AT directly writes project files for the ImageStation from Z/I Imaging.
- Various analytical plotters are supported (e.g. BC2, BC3, Planicomp P series)
- Orientation data are exported in the format of the block adjustment program PATB-GPS. The PATB format is a world-wide standard, and can therefore be imported by numerous photogrammetric systems.

3.6. Overview of MATCH-AT 3.0

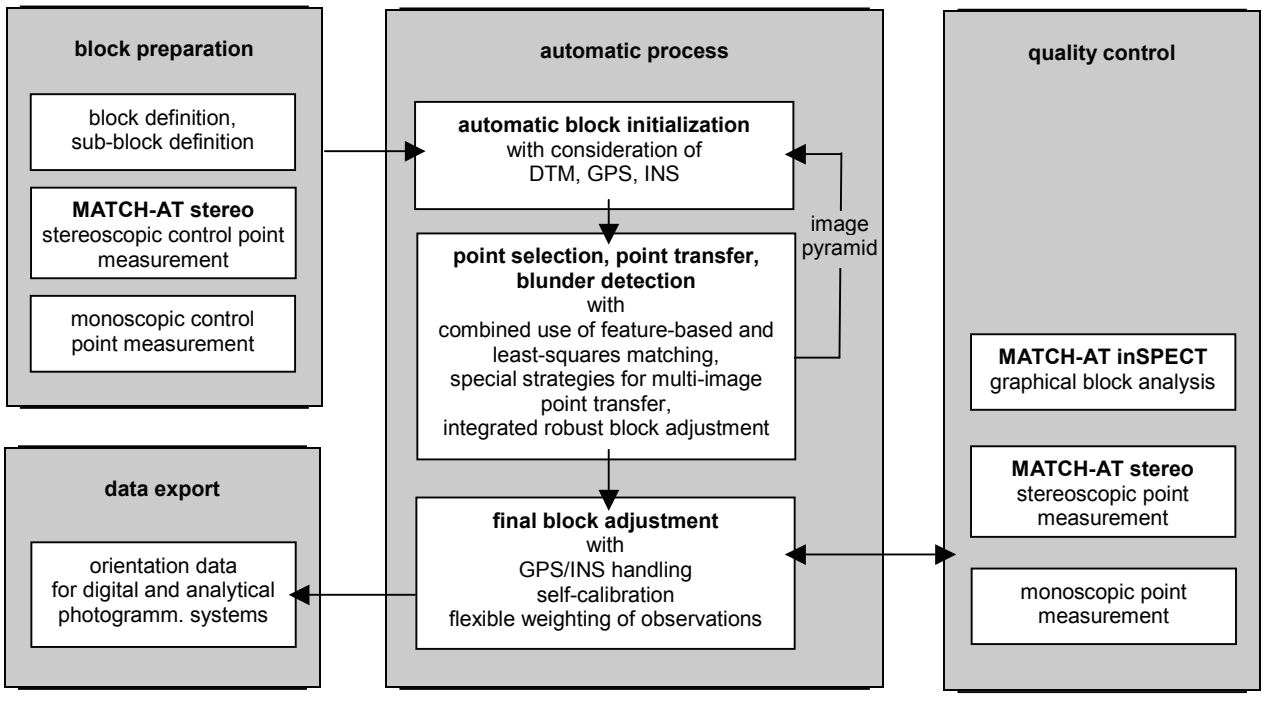

Figure 2: Workflow and features of MATCH-AT 3.0

4. MATCH-AT - INTEGRATED IN INPHO'S PHOTOGRAMMETRIC SYSTEM

As presented during the 19th ISPRS Congress in Amsterdam in July 2000, INPHO is now offering the full suite of photogrammetric products covering it all from image capturing to orthophoto mosaicking (J. Hakala, W. Mayr, 2001). INPHO extended its own product line by innovative new developments (e.g. inBLOCK, inJECT, OrthoMaster), and teamed up with strong and specialized partners who offer complementary products (e.g. Summit Evolution from DAT/EM, USA, UltraScan 5000 from Vexcel Imaging, Austria, and OrthoVista from Stellacore, USA). The new group is called GeoToolBox Team.

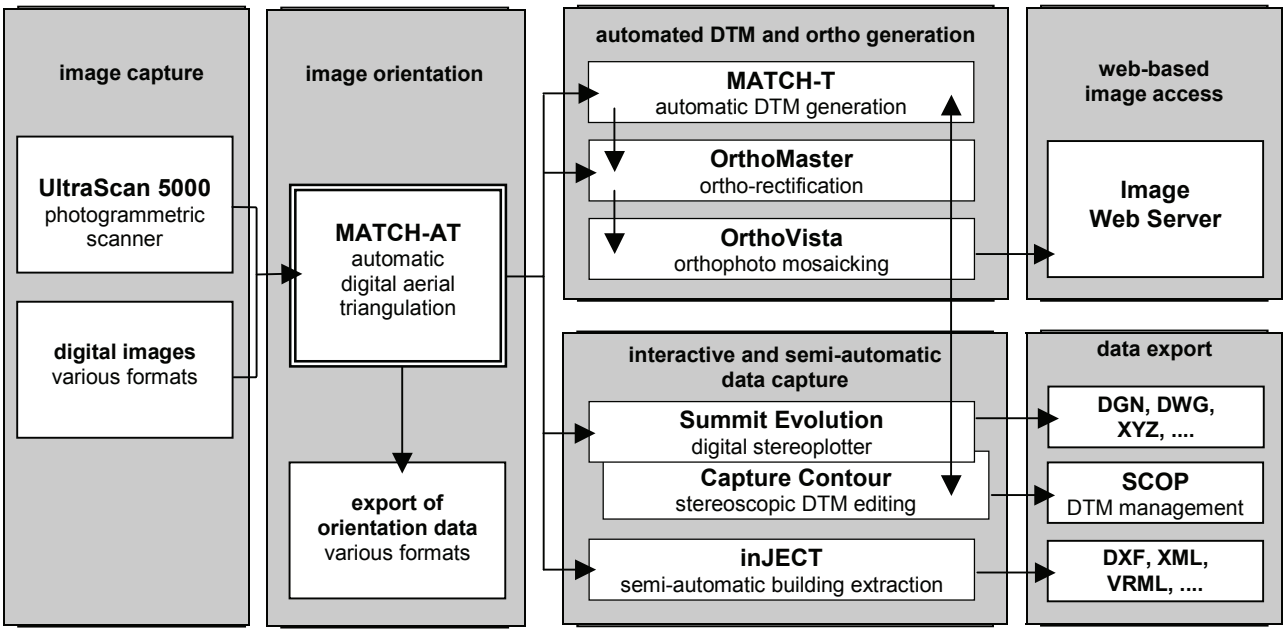

Figure 3: INPHO's digital photogrammetric system

MATCH-AT plays a central role in INPHO's system. All other system components are closely connected with MATCH-AT:

- The next software release of the photogrammetric scanner UltraScan 5000 will generate image pyramids and interior orientation parameters for a direct use in MATCH-AT.
- Summit Evolution (digital stereoplotter), MATCH-T (automatic DTM generation), OrthoMaster (orthophoto production) and inJECT (semi-automatic building extraction) directly read orientation data from MATCH-AT project files.
- MATCH-T Block is a new optional extension of MATCH-T. It generates a seamless DTM for complete blocks as defined by MATCH-AT. Locally the best fitting stereo model is selected with consideration of the MATCH-AT orientation data.
- OrthoMaster is able to run the orthorectification for complete blocks. In automatic mode OrthoMaster determines the necessary image parts from the MATCH-AT orientation data, with consideration of a predefined orthophoto overlap.

5. INBLOCK - A NEW ADVANCED BLOCK ADJUSTMENT PROGRAM

inBLOCK is the new bundle block adjustment product from INPHO. It is based on INPHO's object-oriented multi-sensor XP Class Library which allows the combined use of different imaging geometries and other new sensors, such as GPS, INS and LIDAR. With this innovative solution INPHO presents a most advanced block adjustment product with the following main features:

- Imagery from classical film cameras, digital frame cameras and line sensors such as SPOT can be handled.
- GPS and INS data are rigorously considered. Shift and drift parameters can be applied.
- By the use of data snooping and robust adjustment, inBLOCK offers a sophisticated data analysis.
- Self-calibration is available for the correction of image deformations and for sensor calibration.
- With a free block adjustment (without control points) inBLOCK is able to simulate and analyze a planned block design.
- inBLOCK is particularly prepared for the graphical support of the block analysis. Block overviews can be presented in a flexible way, showing the block configuration, accuracy and external and internal reliability results in graphical form. The user may click to any observation and obtain statistical results.

With the integration of inBLOCK into the next version of MATCH-AT, the automatic aerial triangulation process will benefit from inBLOCK's features, and will reach an even more advanced level of performance and flexibility.

6. CONCLUSIONS

With MATCH-AT 3.0 INPHO offers a leading edge product for automatic digital aerial triangulation. All new requirements like sub-block handling, GPS/INS handling, graphical block analysis, and in future also multi-sensor support are fulfilled by MATCH-AT. INPHO will continue to develop new features and make them available to the photogrammetric community world-wide.

7. REFERENCES

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