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Perspectives for aerial triangulation offered by Z/I Imaging

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ABSTRACT

This paper attempts to summarize the current status of digital photogrammetric workstations and existing products for digital aerotriangulation. An overview is given of the major requirements resulting from several years of practical experience with digital areotriangulation. On the basis of current experience and the latest investigations and research work performed at Photogrammetry Institutes, the paper concludes with an outlook at the prospects for improving the design of digital photogrammetric workstations in the future. The aim is to propel digital aerotriangulation systems to the next generation of digital workstations.

Dieser Artikel versucht den aktuellen Stand digital photogrammetrischer Arbeitsstationen und derzeit vorhandener Lösungen für die digitale Aerotriangulation aufzuzeigen. Es werden einige wesentliche Anforderungen als Erfahrung aus der mehrjährigen Anwendung der digitalen Aerotriangulation aufgezeigt. Auf der Basis dieser Erfahrungen, sowie den neuen bekannten Forschungs- und Entwicklungsarbeiten schließt dieser Artikel mit einem Ausblick zu einem verbesserten Design digital photogrammetrischer Arbeitsstationen. Ziel ist es dabei die digitale Aerotriangulation in eine nächste Generation überführen zu können.

1. INTRODUCTION

Digital aerotriangulation has rapidly proved its high efficiency and can now be considered firmly established in practical photogrammetric work. This statement is borne out by the number of more than 80 systems sold by Z/I Imaging GmbH alone, formerly the Carl Zeiss Photogrammetry Division. Although only a few years have passed since the market launch of automatic aerotriangulation (AAT), AAT has become an indispensable part of the product range of every provider of digital photogrammetric systems. This "paradigm leap" is certainly not only due to long years of in-depth research, but also to the fact that AAT permits a significant reduction in personnel required which constitutes a major cost factor in conventional aerotriangulation.
Even at this early stage after the introduction of AAT, however, the question arises as to whether the indirect determination of orientation parameters by aerotriangulation will not soon be superseded by the method of direct parameter determination using GPS/INS (Heipke, Eder 1998). No definite answer to this question has been found to date.
A look at current AAT implementations shows that, in addition to the purely scientific work such as the development of suitable matching algorithms and strategies, an essential part of the success is attributable to the engineering effort which involves the analysis of existing work cycles and their highly efficient combination with the capabilities of digital image processing techniques. Digital aerotriangulation is therefore an example of the systematic implementation of digital techniques in the conventional photogrammetric processing cycle.
It would appear, however, that the solutions currently available for digital photogrammetric workstations (DPWS) still offer scope for considerable enhancement in the future. The systematic implementation of a digital approach in the production processes can now be followed by a combination of different data and methods to tap further potential of digital processing methods.

This paper attempts to give an outline of the future prospects of digital aerotriangulation, while also addressing the special situation at Z/I Imaging.

2. STATUS QUO

2.1. Digital photogrammetric workstations

The launch of PHODIS AT in 1996 completed the PHODIS® product line as a DPWS, permitting the user to optionally perform all conventional operations either by digital or analog/analytical methods - from the digitization of the analog photographic material right up to orthophoto generation or stereoplotting.
During the last few years, the robustness of the systems has been considerably improved for practical application, and they have been implemented on different computer platforms in response to user requests. Allowance has also been made by all suppliers for the increasing demand for satellite-supported sensors, with several different, comparable systems now being available on the market.
Currently, the first generation of DPWS is available which displays the following major performance features:

Digitization of wet film photos using products such as PS1 PhotoScan or SCAI, and the availability of digital satellite images.
The **application of digital techniques** in photogrammetric processes has been implemented in line with the conventional production cycle. In addition, special functional enhancements such as automatic interior orientation or automatic relative orientation have become successfully established.
The **basis of digital image processing** (DIP) has been created and is provided to the user in the form of tools for format conversion, data compression, image viewing, image data processing, etc.
The **speed** of digital data processing - one of the essential requirements for successful DIP - has now reached a level which permits on-line compression or decompression and on-line resampling at the same time as straightforward data processing or visualization.

For some time now, the ongoing rapid increase in CPU performance, the continuing drop in prices in the computer industry and the dramatic expansion of the Internet have been influencing the development in the field of GIS and, as a result, in photogrammetry. The resultant rapid innovation cycles have a favorable overall effect on the capabilities of DIP and are suitable for initiating the breakthrough to the second-generation DPWS. This development is characterized by the following aspects:

Data management concepts with Internet capabilities are known and are currently being implemented. One example is the "Image Server", a prototype of which has already been presented by Z/I Imaging Corp during the ASPRS 1999 in Portland (USA).
Digital cameras will provide increased radiometric resolution, permitting a significant improvement in the signal/noise ratio. This will open up new possibilities to digital photogrammetry, especially in the field of visualization and interpretation.

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The systematic **upgrading of the AAT block approach** using e.g. the IDP concept (Braun, 1997) which includes continuos stereo viewing and an end product-oriented approach to existing image data as its essential elements.
Upgrading of existing techniques, e.g. by OneEyeStereo®. With this function existing matching techniques adopted to automatically guide the floating mark on the terrain surface.

2.2. Digital aerotriangulation

Whereas the AAT modules currently available still left varying impressions in the OEEPE Test of 1997 (Heipke, Eder, 1998), the OEEPE workshop "Automation in Digital Photogrammetric Production" held in Paris from June 22 to 24, 1999 demonstrated that all suppliers have now positioned their products in largely the same accuracy range.
To permit an assessment of the status of current AAT packages, let me point out the following key points on AAT.

- The theoretical accuracies of LSM matching of σ_0 = 0.2 pixel and of simultaneous multi-image matching of σ_0 = 0.1 pixel are attainable in practical use.
- Large-area coverage involving 100 to 300 points per image is required to ensure high block stability (Heipke, Eder 1997).
- Up to a factor of 1/5, compression has only a negligible influence on the accuracy of point transfer using LSM (Hahn, Kiefner 1998).
- Pixel sizes of less than approx. 20 µm do not significantly increase the accuracy of tie point measurement (Ackermann, Krzystek, 1997). However, high resolutions are required for the clear identification of control points.
- Depending on the block involved, overall operator processing time has been reduced by up to 80 % (for PHODIS AT). The time required for automatic tie point measurement ranges between about 6 and 30 minutes per image, depending on the terrain. Times of approx. 2-3 minutes per image were attained in recent measurements using PHODIS AT Version 4.1.0.

During the last year, major improvements have been achieved in PHODIS AT through modifications in the detection of multiple points. This ensures improved correlation of the strips and hence higher block stability. Table 1 shows the marked increase in the number of 4- to 6-fold multiple points in PHODIS AT version 2.1.0 as compared to version 2.0.1.

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Versio	elim Blunder (%)	av.no.of tie pts. imag	No.of multiray point						σ_0 (µm	σ_{FI} (µm
			tot	2	3	4	5	6		
V2.0.	10	358	131	824	413	56	15	7	6,7	6.4
V2.1. (P3=1	14	256	895	639	119	**65**	**21**	**51**	6.3	7.3
V2.1. (P3=3	14	333	110	667	243	**97**	**30**	**67**	6.5	7.3

Table 1: PHODIS AT results for the Montserrat block (OEEPE Test 1999).

This result can easily be illustrated. Although Fig. 1 only shows the points relevant for the linking of the strips, the good distribution of the points over the area is clearly recognizable.

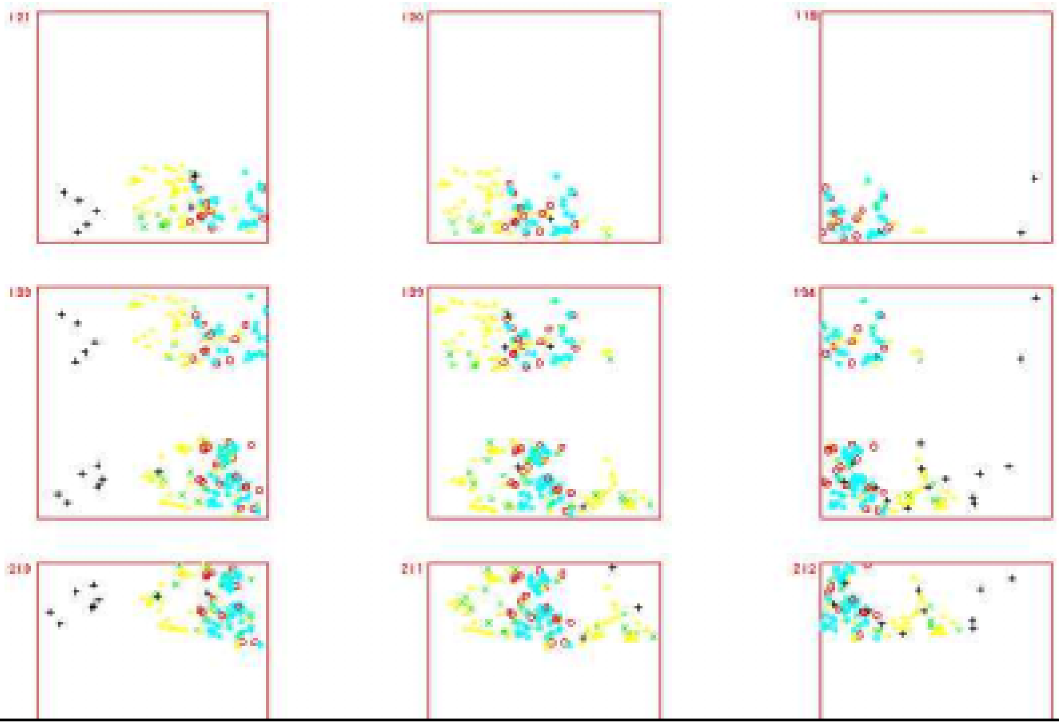

Abbildung 0 : PHODIS AT Strifenverknüpfung für den Block Montserrat (OEEPE Test 1999)

Figure 1: PHODIS AT linking of strips for the Montserrat block (OEEPE Test 1999).

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3. PROSPECTS

3.1. Requirements

Automatic aerotriangulation has been available on the market as a commercial product and has been in worldwide use for approx. 3 years now. Despite ongoing enhancement, various features are still in need of improvement. This applies to varying degrees to all AAT programs currently available.

- Improved quality control
- Integrated bundle block adjustment and possibly free network adjustment
- Stereo measurement of control points
- Open programming interfaces for special adaptation in existing work environments

Improved quality control is one of the points of paramount importance. This must also be seen within the context of what training qualifications a user must have to use an aerotriangulation result. Improved quality control could be achieved, for example, by a roam and zoom procedure across a block, in which the graphically edited results of block adjustment which form the basis of the image information are used for quality checking.
Another point of great importance is the so-called "self-checking mechanisms", as the large number of observations make it difficult to achieve easy interpretation of the bundle block adjustment results. For self-checking purposes, the result of an internal, free network adjustment should be used.

3.2. Possible developments

Current development and research work is revealing various possible applications of aerotriangulation measurement. On the one hand, this includes ideas and trends that have been previously discussed in various publications, and on the other hand, general statements can be made concerning the potential of known techniques. Some of these aspects will be addressed in the following.
Logically enough, the generation of a large number of well-distributed points in the image, as specified by Heipke, can be used as input for DTM generation. This idea has already been published (Krzystek, 1996) and has presumably been implemented in Match T.
Direct georeferencing by the combined use of GPS/INS systems (Cramer, 1997) will certainly enjoy increasing popularity in the near future. This is reflected by the growing number of systems which will have a favorable effect on the purchase price in the long term. Secondly, the high accuracy attainable has reached an acceptable level. This will also lead to a reduction in the number of control points required. In the long term, aerial photographers may therefore be able to do without the costly procedure of signalizing. Points which are clearly visible in the image can then be subsequently measured using GPS.
The optional combination of sensors will gain increasing importance in the future, with possible applications including the combined processing of terrestrial, air-borne and satellite-based photos. The adaptations required for the processing of images obtained with new, aircraft-borne digital

cameras, such as a 3-line sensor which makes special requirements in this respect, must also be seen in this context.
Attempts to implement automatic absolute orientation have been under way for some time now, ranging from the identification of drain manholes (Derwniok, 1996) to the creation of a control point database e.g. on the basis of roof points. A further possibility is the use of additional information such as existing vector data. For satellite imagery this has been already demonstrated (Hild, Fritsch 1998).
The user-friendly operating concept presented by Braun in 1997 and the block approach will continue to be incorporated in digital photogrammetric systems. If the user-friendly, end product-oriented approach is pursued to its logical conclusion, it is perfectly possible that photogrammetry will become a mere tool for the acquisition of information.

3.3. Z/I Imaging products

After the approval of the joint venture by the US antitrust authorities, Z/I Imaging will have two complete DPWS systems in its product range, both firmly established on the market. PHODIS has its customer base on a UNIX platform, while ImageStation is based on Windows NT. Both products have been retained in the new portfolio of Z/I Imaging. This means that PHODIS on UNIX will continue to be available in addition to ImageStation, the future-oriented because NT-based product.

4. SUMMARY

Photogrammetry is currently undergoing a phase of change. The challenge consists not only in the all-round transition to digital photogrammetry, but also in the transition to second-generation DPWS which is currently under way. This process will be characterized by short innovation cycles based e.g. on Internet applications and by new requirements emerging from new markets. Different data sources such as GIS databases or various sensor data will be jointly processed in the future.
AAT has earned itself a place within the DPWS chain. The current operating principle which has the primary function of controlling the measuring process will only play a secondary role in the future. The demand for self-checking mechanisms and a block-wide, end product-oriented approach will have a considerable impact on the importance of AAT. The next generation of DPWS will be characterized by the addition of further data sources such as GPS/INS measurements and the combination of operations which still run separately at present (AAT and DTM).
The importance of photogrammetry as a tool for geo data acquisition and visualization will remain. This is the meaning behind the sentence "Now we must talk about the big vision in trying to integrate photogrammetry and remote sensing into geoinformatics." (Konecney, 1998).

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