Notes on Digital Aerotriangulation and R&D Potential in Photogrammetric Applications

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Abstract

Two aspects on the digital photogrammetry are discussed in this paper: (a) accuracy analysis, experience and the necessity of additional program on the automatic digital aerotriangulation (AT) are first described. Here not only the feedback of the automatic procedure from production but also some additional programs beside the commercial ones are explained in details; (b) On the base of one program package, "DAP" (Digitaler ArbeitsPlatz) the potential of Research and Development (R&D) in the daily production is discussed in this paper.

Zusammenfassung

Zwei Aspekte über die digitale Photogrammetrie sind Inhalt dieses Beitrages: (a) Analyse der Genauigkeit bzw. Bericht über die Erfahrungen und die notwendigen Zusatzprogramme für die digitale Aerotriangulation (AT) werden beschreibt. Dabei soll nicht nur das Feedback über das automatische Verfahren durch die Produktion sonder auch die Zusatzprogramme in Detail betonet werden; (b) Auf Basis des Programmpacketes „DAP" (Digitaler Arbeits-Platz) wird das Potential der Forschung und Entwicklung (F&E) für die tägliche Produktion diskutiert.
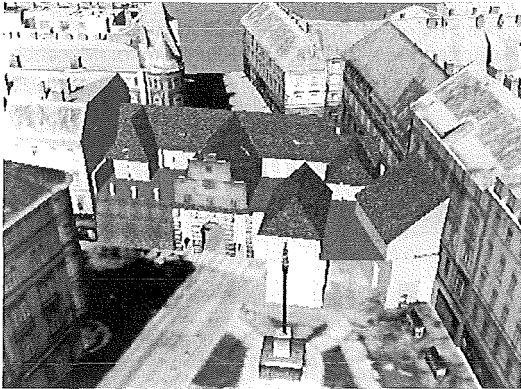
1. Introduction

For a dynamic developing city, like Graz, it is long enough for about four years to have a total new aerial photo to cover the whole city area. In order to bring these high-quality photos into photogrammetric production as soon as possible, aerotriangulation (AT) becomes a must step. In the year of 1992, when the digital aerial photos and certainly also the automatic triangultion procedure are not so popular as today, Graz has finished its AT with traditional analytical method. It was and is a time consuming and very patience-necessity job, but when everything well done, it gave and gives a reliable and precise result [1], [2]. Began in the year of 1994, the Graz City council, especially the department of Surveying has been trying to apply the digital aerial photo in production. This effort is now spreading into several directions, e.g. digital AT, digital orthophoto production, digital workstation (DAP- Digitaler ArbeitsPlatz) and 3D (three dimensional) city model. In later paragraphs of this paper digital AT and DAP will be described in detail, here some words about 3D city model may be given.

As one of the newest possibility from digital world, 3D city model is being used intensively by the department to present its surveying result in different application fields. It can used to display the past, the present and the future of the city parts during different discussions in live. Fig.1 shows an example. For city planning and administration, it is well known that the Virtual Reality (VR) plays more and more important figure. It can be used to display and analyse the spatial structure, the form of buildings and to visualise interactively alternative projects.

Nowadays existed 2D and 2.5D GIS (GeoInformationSystem) data are converted automatically into 3D city model [3]. The software GIS3D is now used for this purpose with very little operator intersection. But the digital facade photos

and the aerial photos for terrain have to be processed manually. In the near future it should be possible that the necessary 3D information be extracted directly from digital images, surely with automatic possibility.
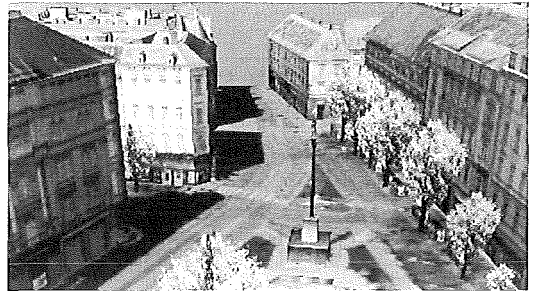

Fig.1: The past (left) and present (right) situation of Eisernes Tor in Graz

2. Applied Hard- and Software for digital AT

Automatic tie points extraction was carried out on SiliconGraphics Indigo[2] workstation run with operating system IRIX6.2. Adjustment computation was done on a Pentium PC with windows 95.

2.1. The necessary storage capability

The flight was carried out with a RMK camera which focal length is about 305 mm in early spring of 1996. The average scale of the colour photos is about 1/3700 and were scanned with SCAI of a 28 micron meter μm) resolution. That means each digital colour photo needs 214 Megabytes (MB) places in order to be stored on hard disk (HD). For the purpose of AT they were reduced to black/white images, in this way the size of each image was reduced to 71.4 MB. The pyramid size of each photo is about 23.5 MB. The computation and separate storage of pyramid is a must step for later automatic interior orientation and tie points extraction.

Altogether 22 Gigabytes (GB) HD was connected to the SGI Indigo[2] Workstation on which the software package PHODIS-AT was installed. Considering the limitation of HD and the different quality categories of control points in different parts of Graz, we separate the whole area into four sub-blocks like that in Fig. 2.

Roughly each subblock has 180 images, that takes about 17 GB away from HD. Before flight,

the control points are signalised using the schema as in Fig. 2. So we can manage the sub-blocks individually either by automatic tie points extraction or by adjustment computation. It is the same for tie point extraction whether the whole area be processed at one time or separated into several blocks. But for the adjustment computation with PATB-GPS, it is really to recommend to finish the whole area block by

block. In the year of 1997, we did have tried the whole block to be computed at one time, and we did not get any result due to break down of the program. As it will be described later, such a break down makes it impossible to continue the rest of work.
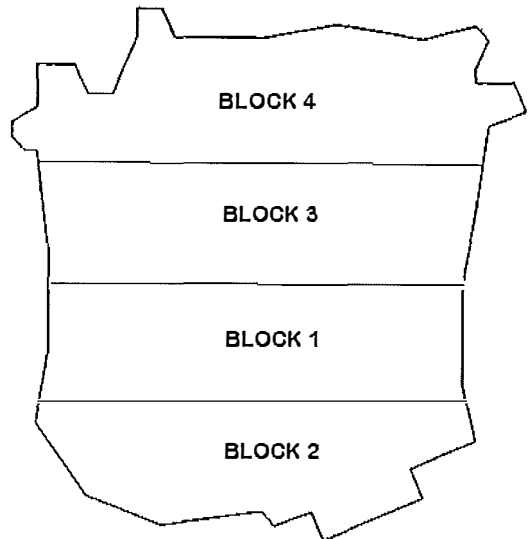

Fig.2: Separation of sub-blocks

2.2. The applied software

There were three main program parts which had been used for the AT. PHODIS-AT was used to compute tie points, PATB-GPS to get adjust-

ment results and additional program package (DAT) was developed to process the computation result from PATB-GPS on one side and to convert different formats on another side.

2.2.1. PHODIS-AT

The strategy of PHODIS-AT is using huge redundancy of tie point number to guarantee the quality of result. The advantage is that with the images like ours, large scale images from typical European city area, after careful preparation, the procedure works without operator intersection. At the same time, result with such a redundancy contains certainly relative high percentage of gross error. The following table shows one example for a block of 169 images.

sorting and elimination, as one iteration. For the tie points from PHODIS-AT, it needs about ten iterations to get the last acceptable results. Each iteration takes about 2 hours, we need generally 3 work-days to finish the computation of a subblock.

2.2.3. DAT- the additional program package

As described before, usually PATB-GPS is not to be considered to processing up to 1000 points per image. Due to that PHODIS-AT gives a great amount of redundancy, we are forced to make program to do the critical points sorting and eliminating of critical points from input file. After the first computation, this program gets out all the critical points either of tie points or of

	Point number before elimination	Percentage Of the total number	Point number after elimination	Percentage Of the total number	Percentage of elimination
1-fold	17	--	22	--	−29.4
2-fold	62495	74.2	57661	79.6	7.7
3-fold	16872	20.0	12089	16.7	28.3
4-fold	3734	4.4	2041	2.8	45.3
5-fold	1017	1.2	516	0.8	49.2
6-fold	140	0.2	68	0.1	51.4
Σ	84275	100	72397	100	14.1

Table 1: Distribution of tie point before and after the elimination

As we see, about third parts of 3 fold points and half of 4 ~ 6 fold points were eliminated after the last computation. Almost 80% of tie points are 2 fold one. The solidity of the blocks can be endangered. In practice, as it was proved later, the orientation parameters which were computed from this result have to be improved by operator from time to time.

2.2.2. PATB-GPS

This adjustment computation program is suitable for classic analytical method. For the results from the program like PHODIS-AT, functions in two aspects have to be improved. (1), even with automatic gross error detection, the program crashed down when the percentage of gross error was high enough. Under this situation, it is very awkward for the operator. Before examining the result of first computation, the operator has almost no chance to get any control of the tie points which are more than 500 in each image. (2), at least two additional functions need to be accompanied, namely, for critical point sorting and elimination from the input file. If we define all the steps, computation with PATB, control point analysing, critical points

control points which are selected with certain criterion. As usual the critical control points are analysed and managed manually. Due to the great number, the critical tie points are deleted immediately from input file if they are appeared in the sorted output file. This procedure is repeated several times until the rest critical points are under demanded criterion.

Before the computed results to be transferred to analytical plotter, some statistic values are given out. Following ones may be very important: the number of critical points, the maximum residuals of critical points and the residuals distribution in image. This work can be done by DAT.

3. Result analysis of digital Aerotriangulation Graz 1997

3.1. Requirement on the flight

Compare to the analytical AT, automatic digital AT has more requirements on flight. The following situation shows that flight manner should be also considered before be carried out. Flight should be done in traditional manner (see

Fig.3). In the fact that the time interval between photography of neighbour strips should be as short as possible.
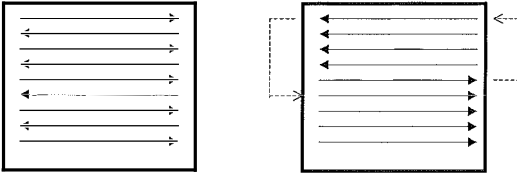

Fig.3: Flight manner

The time interval between neighbour stripes in Fig. 3.b is longer as that in Fig. 3.a. If the matching points are extracted from shadow features, this longer interval means bigger error at the same position and more inaccurate points. Fig.4 shows a practical example.

3.2. The accuracy comparison

The accuracy of the digital AT of large scale image in city area is comparable to that of analytical AT with slight worsening. The table 3 and table 4 show the results of accuracy comparison of the automatic digital AT and traditional analytical one. The aerial photos from flight 1992 are very similar to that of 1996, the photo scale is about 1/3700. In table 3 the values are direct from computation protocol of PATM (1992) and PATB (1997). The statistic control value are summarised in table 4, where in 1992, 12 models were checked by 6 operators, and in 1997, altogether more than 800 points (existed sewer lid points and old control points which were not be taken into the computation of adjustment) in 54 models all over the four blocks were verified by 3 operators.

Fig.4: Tie point 72359 is extracted from tree shadows. As we see it was moved in lower strip due to shadow moving, even the feature positions were exact the same location in both strips.

In image system	Block 1 (μm)	Block 2 (μm)	Block 3 (μm)	Block 4 (μm)
σ_0 (plan., 92)	$\pm$ 5.91	$\pm$ 8.51	$\pm$ 7.71	–
σ_0 (height, 92)	$\pm$ 22.10	$\pm$ 23.12	$\pm$ 23.02	–
σ (Naught, 97)	$\pm$ 10.87	$\pm$ 7.16	$\pm$ 7.93	$\pm$ 10.66

Table 2: Precision comparison of computation protocol

In terrain system	Control points (cm)	Sewer lid (Measurement 92)
σ_B (Planimetry, AT92)	$\pm$ 5.2	–
σ_B (Height, AT92)	$\pm$ 7.0	–
σ_B (Planimetry, AT97)	$\pm$ 6.1	$\pm$ 12.48 (cm)
σ_B (Height, AT97)	$\pm$ 8.0	$\pm$ 12.32 (cm)

Table 3: Precision comparison of points measurement

3.3. Performance and efficiency comparison

For most of photogrammetric professionals it may be very interesting to know the performance and efficiency improvement of the automatic method. The performance is anyway greatly improved when we consider over the analytical procedures, block planning, tie points selecting or marking, tie points measurement image by image or model by model and so on. What we need for the new method is to prepare the blocks, or tell the program from where to get what. Here we need not any special instrument.

The most time consuming job during preparation is image transferring between hard disk and DAT tapes. But we hope that in the near future some better media than DAT tapes can be used for digital image storage. Another factor is the familiarity to the software of human operator and number of software leaks. The detailed information about time comparison can be read from the paper of Mr. Ganster in this issue.

4. Necessity of R&D in the Photogrammetric Production

One example of R&D in the photogrammetric production is the program package DAT (Digital AeroTriangulation). It is mostly used for critical points sorting, elimination as well as analysing the adjustment result with statistic method after the computation. One can imagine that without these programs what a terrible situation a operator will face when he has to manage more than eighty thousend points in one block manually.

According to the daily demands of photogrammetric production we have made the sub-
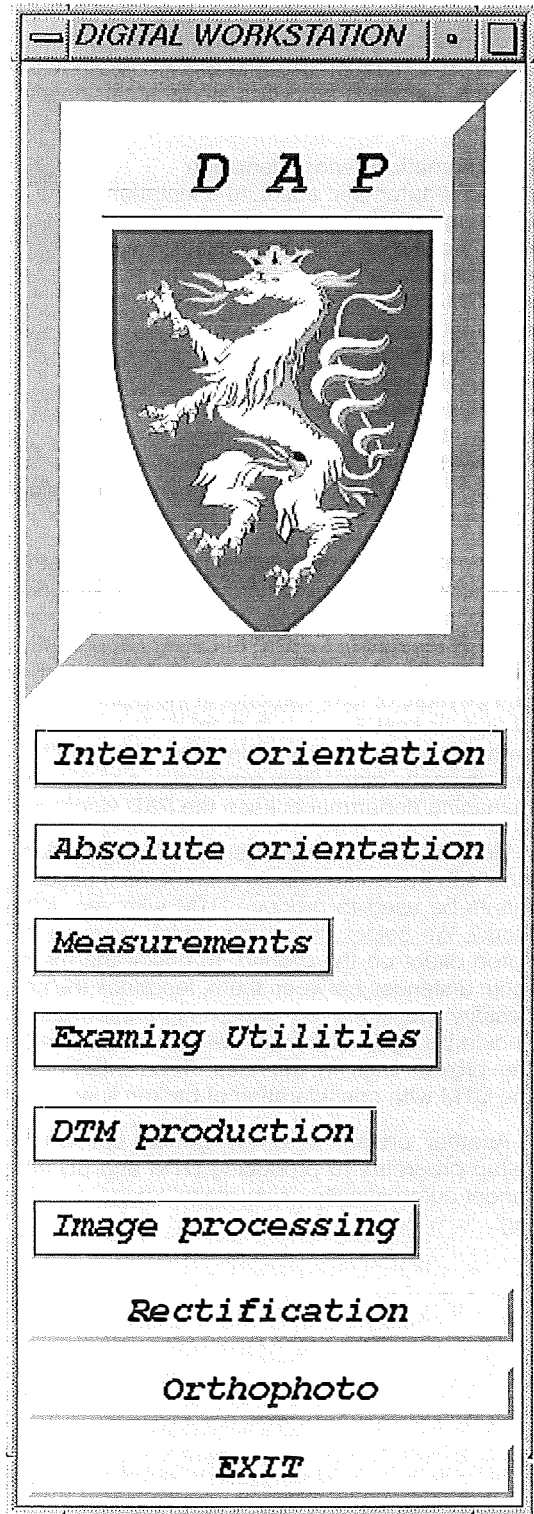

Fig. 5: GUI of program package DAP

routines of digital workstation DAP during last three years. Amounts of utilities were made under such a situation like that of DAT. As showed in Fig.5, following functions are included now in DAP:

- Automatic interior orientation
- Semi-automatic absolute orientation
- Image points measurement
- Geodesic coordinates measurement
- Digital image rectification
- DTM checking and interpolation
- Profile computation
- Contour line production
- Volume calculation
- DTM 3D viewing
- Two DTMs visual comparing
- Overlay orthophoto on DTM
- Big image (>400 MB) display and processing
. . .

Even the existed extensive software market in the world, we can not imagine that our production can be carried out without support from R&D. Three reasons seem to be very apparently. First, what you get is not exact what you need, it can be more or less. Second, in the point of view of time or cost, it is much more economic if the software can be produced interiorly. Third, different demands direct from production and various managing departments keep the R&D vigorous.

Here is one example from DTM production. How can the existed photogrammetric measurements be used to produce DTM with very little work? We select the points which were measured direct on the ground, to check the maximum distances between them, feedback the necessary positions on which high information should be again obtained. We select continually the broken lines in the area. Then interpolate the DTM with consideration of broken lines.

Another project is being carried out which setup programs to producing DTM and 3D city model automatically using digital image matching.

5. Conclusion

As reported from other applications [4], automatic tie points extraction from digital aerial photos is applicable in daily production either in the point of view of accuracy or of efficiency. As it is showed in this paper, some preparations have to be done from flight to adjustment computation carefully. For large scale image in city area, photo flight should be carried out in traditional manner. Distribution of signalised control points should be considered together with sub-block size.

Automatic digital AT, as rather new method, shows room for improvement in following points: (a) the intelligent degree of automatic tie points extraction can be higher, that means the percentage of gross error should be lower; (b) PATB-GPS should be adapted to the new situation in (b.1) integrating critical points sorting and eliminating functions; (b.2) be able to manage higher percentage of gross error.

On the base of DAP, the necessity of R&D directly supporting to production is explained here in this paper. We can conclude that R&D makes an efficient and variant production possible and at the same time the different demands from daily production and city management vitalise the R&D.

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