FEASIBILITY OF USING AUXILIARY DATA FROM AN INERTIAL NAVIGATION SYSTEM FOR AERIAL TRIANGULATION

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and Universidad Nacional de San Juan.
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Abstract

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1. Introduction

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In that paper, and before dealing with the subject itself, Ackermann expresses his suprise at the poor utilization of traditional auxiliary data such as statoscope and airborn profile recorder. The rest of the paper describes the Bodensee test carried out by the Stuttgart University and clearly shows the good quality and the interesting potential of auxiliary data provided by the Computer Controlled Photo Navigation System (CPNS). As a suggestion a very interesting possibility is mentioned: Aerial triangulation with very little or without any ground control.

In view of these promising circumstances, during the VI Congress of the Argentine Society of Photogrammetry held in Corrientes last year, it was recommended that the "II Brigada Aérea" of the Argentine Air Force, together with the Universities of San Juan and Tucumán should carry out tests in order to investigate the quality of the auxiliary data provided by the Photogrammetric Integrated Control System (PICS) owned by the "II Brigada Aérea". In fact, some experiences had been already made in this last establishment by Walter Olmos who, working with isolated models, in a Zeiss Planimat, could obtain promising results, feeding directly to the projectors, some of the exterior orientation elements from the PICS.

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This test, carried out in 1982 around the Bodensee /1/, was designed to study the general performance of the CPNS and it was also used by the University of Stuttgart to investigate the quality of the auxiliary data provided by this system for aerial triangulation.

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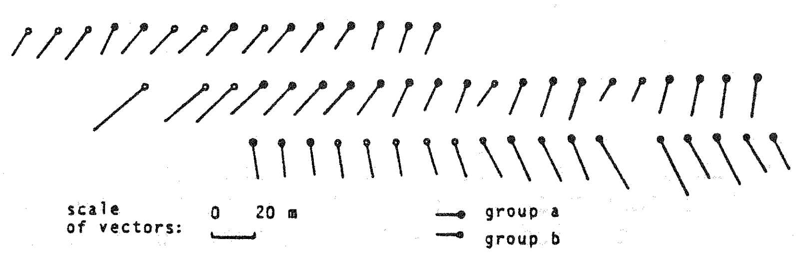
The first direct comparison of both types of coordinates yielded a pattern of discrepancies of a clear systematic nature. In fact these discrepancies were practically constant within a strip (fig.1) and practically no drift effect was noticeable.



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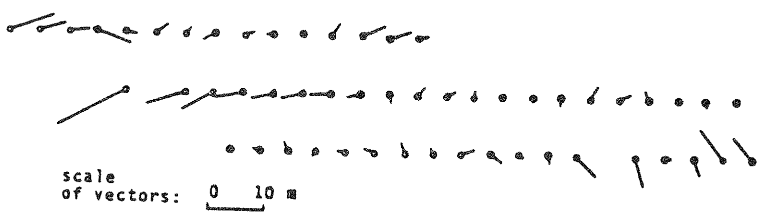

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b) No presignalized points were used and natural points were not always clearly defined.
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d) The photo navigation system to be studied was an inertial one, the PICS, and not the CPNS.
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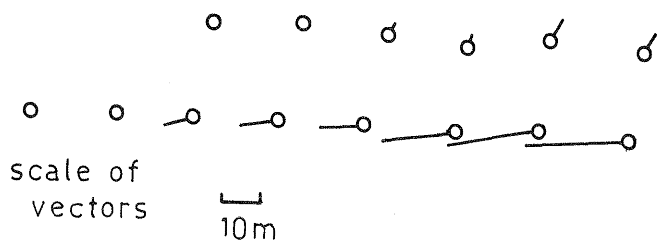
At the beginning of this year this small block was triangulated first in a Wild A 10 at the "Centro de Fotogrametría" of the San Juan University and in a Zeiss C-100 Planicomp at the Division of Photogrammetry in Agua y Energía Eléctrica. In both cases the adjustment was carried out with the COBLO 7RER program of the University of Tucumán. This program is based on the COBLO 7R version /2/ in which Robust Estimators have been incorporated for the detection and automatic elimination of gross errors /3/. Both COBLO 7R and COBLO 7RER perform block adjustment by independent models solving the 7 absolute orientation parameters simultaneously. To study the behaviour of the angular values ω an φ, the newest COBLO version, COBLO HR, which perforns block adjustment by bundles, was used.

3.1. Planimetric coordinates of camera stations

When the direct comparison between PICS coordinates and camera stations determined by the block adjustment of Planicomp measurements(COBLO 7RER) was made, a rather irregular pattern of discrepancies was obtained. Things changed a lot when both strips were treated separatly making two similarity transformations, forcing the coicidence between both types of coordinates in the two first perspective centres of each strip (fig.3).



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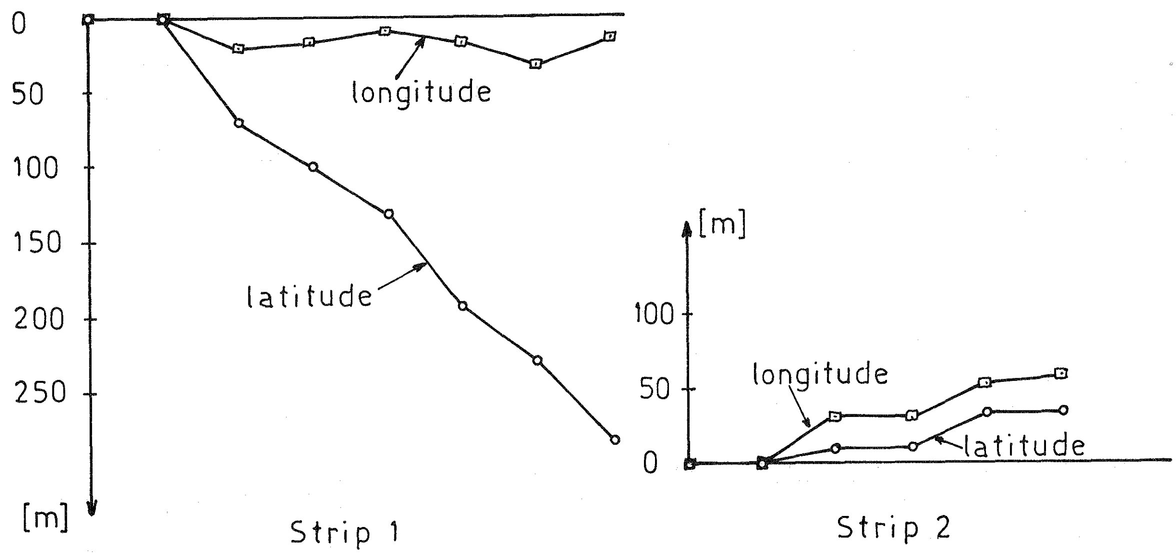
This pattern is different from that of fig.1, but it yields a picture of a systematic nature with a rather clear drift effect. This drift effect is also evident in fig.4, where the discrepancies in latitude and longitud (expressed in meters) are plotted.



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Looking at this pattern of discrepancies, it is clear that PICS coordinates can also be used in a combined adjustment, according to Ackermann /1/, introducing additional equations of the type:

$$X_j^{PICS} + V_{xj} + (a_o + a_1 X + \ldots) = X_j^{PC}$$

$$Y_j^{PICS} + V_{yj} + (b_o + b_1 X + \ldots) = Y_j^{PC} \qquad (1)$$

Where X_j^{PICS} , Y_j^{PICS} are PICS values, X_j^{PC} , Y_j^{PC} , are the unknown coordinates of perspective centres which relates equations (1) with the observation equations of perspective centre j in an adjustment by independent models. The unknown parameters a_0, a_1, b_0, b_1 will establish the connection with the X, Y datum and take care for the drift effect, see /1/.

After removing systematic discrepancies by a similarity transformation using all points, the average point position error corresponding with fig.4 are: for strip 1, 14 m and for strip 2, 9 m. This residual erros of 14 m and 9 m, which will not be compensated by equations (1), are rather big when compared with the residual of 3.6 m reported by Ackermann in the Bodensee test, see /1/.

Care should be taken in considering the average discrepancies found for PICS data in Paranå test. The two strips are very short and the photoscale is too large, which means a very low flight. Considering that low altitude flights are subject to turbulence that can disturbe the performance of PICS, two new flights for the present research are planned by the II Brigada Aérea in the provinces of Tucumån and San Juan with photo scales of 1:20000 and 1: 40000. It should be born in mind as well that the PICS equipment used is rather old and surely the new equipment has a better performance.

3.2. Angular Values

PICS provides also the angular values ω, φ and $\varkappa$ of camera stations. To investigate the accuracy of the values ω and φ ($\varkappa$ readings have a lower resolution) a bundle block adjustment of Planicomp measurements with program COBLO HR was performed. The program COBLO HR (for "Compensación en Bloque por Haces de Rayos") was recently completed at the University of Tucumån /4/. It is, as the former COBLO programs /2/, a general solution. It can accept blocks of arbitrary shape and overlap and the input of data is as userfriendly as possible. The requirements of core memory are small.

The direct comparison of PICS and block adjustment "true" values was surprisingly good (table 1 and 2).

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As it is apparent from tables 1 and 2 the differences between PICS and "true" values remain practically constant. This constant could be determined by calibration or computed in the bundle adjustment (a_0 in equations (1)). No drift effect is observed and the precision of ω and φ is not far from 2 or 3 centigrades.

Of course, the same remarks made in 3.1. are here also valid. To determine reliable values of final precision for ω an φ, tests implying bigger blocks will be necessary.

4. Some possibilities of introducing ω and φ in an adjustment by bundles

Regarding the benefits of including attitude data in the combined block adjustment, Ackermann considers that "The effect of attitude data on the joint block adjustment has not yet been investigated closer. Their effect will be less marked, but an overall solution will have to include them"/1/. This assertion is true if auxiliary data is introduced with a reduced weight in order to improve the precision of block adjustment or in order to reduce ground control requirements. There is, however, another possibility of treating auxiliary attitude data. Such possibility is being now studied at the University of Tucumán and can be summarized as follows: In large unmapped areas, where ground control establishment is very expensive, it can be convenient to introduce observation equations of ω and φ with a big weight in an adjustment by bundles. Thus, the errors will be greater than in correctly adjusted block, but there would not be the unfavourable error propagation which is present in the aeropolygon, for instance. This opens also the possibility of managing strips and blocks with ground control only at the beginning of the strip or of each strip of the block. If the accuracy of ω and φ were of 2 centigrades, as it is provisionally confirmed by the Paraná test, the final attainable accuracy on the ground coordinates would still be good for many purposes. This assertion is suggested by the results of some computer simulations which are now being carried out at the University of Tucumán.

The first fictitious examples processed started from an error free block in which the following errors were introduced:

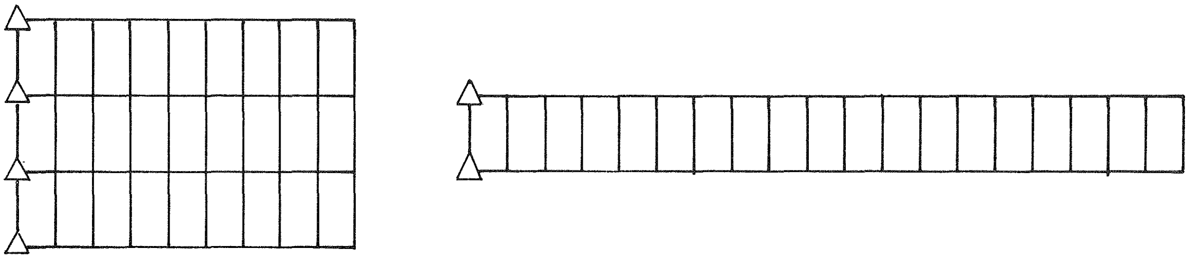
a) Random errors in photo-coordinates, with 10μm (microns) of standard deviation.

b) Final exact camera positions with random errors of a standard deviation of 2 centigrades in ω and φ .

The observation equations corresponding to ω and φ were given a big weight in the adjustment by bundles. Thus, the cameras can be considered as fixed in these two angles. Two of the computed examples are presented here:

1) A block of 3 strip of 10 photographs (9 models) each with ground control only at the beginning of the strips(fig. 5). In this case the average standard deviations (in microns in photoscale) computed from 72 check points are:

$$\sigma_x = 123\mu ; \quad \sigma_y = 72\mu ; \quad \sigma_z = 38\mu$$



△ Planialtimetric control points

fig. 5

The accuracy of Z coordinate can be considered as very good. The lower accuracy in X and Y can be substantially improved with planimetric ground control at the corners of the block.

2) A strip of 20 photographs (19 models) with ground control only at the beginning (fig. 5). In this case the altimetric accuracy is still very good:

$$\sigma_z = 58\mu \text{ (62 check points)}$$

The accuracy in X coordinates (scale error) deteriorates, however, sistematically. Thus, for long strips it will be better to have at least one planimetric ground control at the end.

Another processed example included systematic errors in in photocoordinates as well. Sistematic errors of types indicated by Ebner /5/ were introduced in photocoordinates. The results were also very good, especially in the altimetry.

It is considered that these results are interesting in spite of the fact that resulting errors in ground coordinates are worse than those which can be obtained in a block adjustment with an optimal ground control distribution. In large inaccessible areas, to obtain a precision in altimetry of 1 m from 1: 20000 photography or 2 m from 1: 40000 photography with control only at one side of the area (beginning of the strips) can be a very economical and good solution in many situations.

5. Further tests

The Paraná test is only the beginning of a research project which includes other flights with the same purpose. These flights, two of which have been already flown in the province of Tucumán, were planned to obtain small scale photography. In this way the quality of PICS data will be judged at the most appropriate scale for its use.

Due to unexpected rains in April, the ground work corresponding to the flights flown in Tucumán could not be completed. It is expected, however, that for the KYOTO Congress, some results of these new tests will be presented.

6. Conclusions

The Paraná test, although not complete, shows interesting possibilities of PICS data for aerial triangulation. More research is needed to obtain reliable figures of the real potential of this data.

Large South American countries should encourage this type of research because this technique can offer a very efficient and economical possibility for mapping large and inaccessible regions.

Aknowledgment

This research would not have been possible without the invaluable support of the "II Brigada Aérea" of the "Fuerza Aerea Argentina" and the constant encouragment of the Vicecomodoro Roberto F. Cardozo. To them the authors are deeply indebted.

Very special thanks are given to Walter Olmos. He was in every detail of this work and has suggested interesting ideas.

Thanks are also given to Dr. Ricardo Passini for his kind cooperation that made possible the measurments in the Zeiss Planicomp, to Juan C. Yacuzzi who took under his responsability all aspects of the ground work, and to Eduardo Piatti for having supervised all the work in the Wild A 10 instrument.

Last but not least the authors thank the private firms Aeromapa and Carfoto for financial support.

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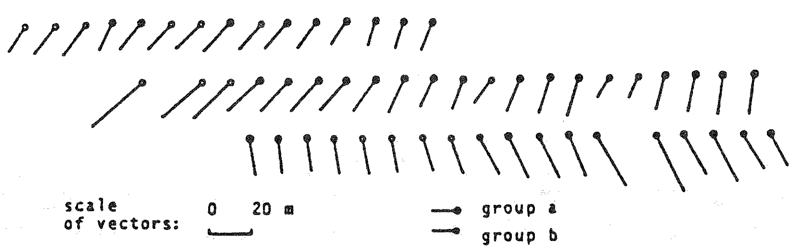

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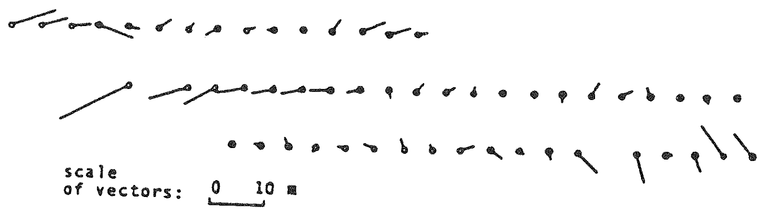

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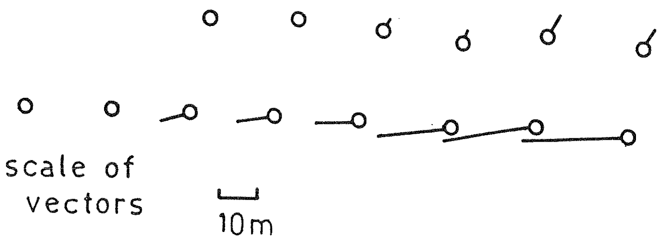

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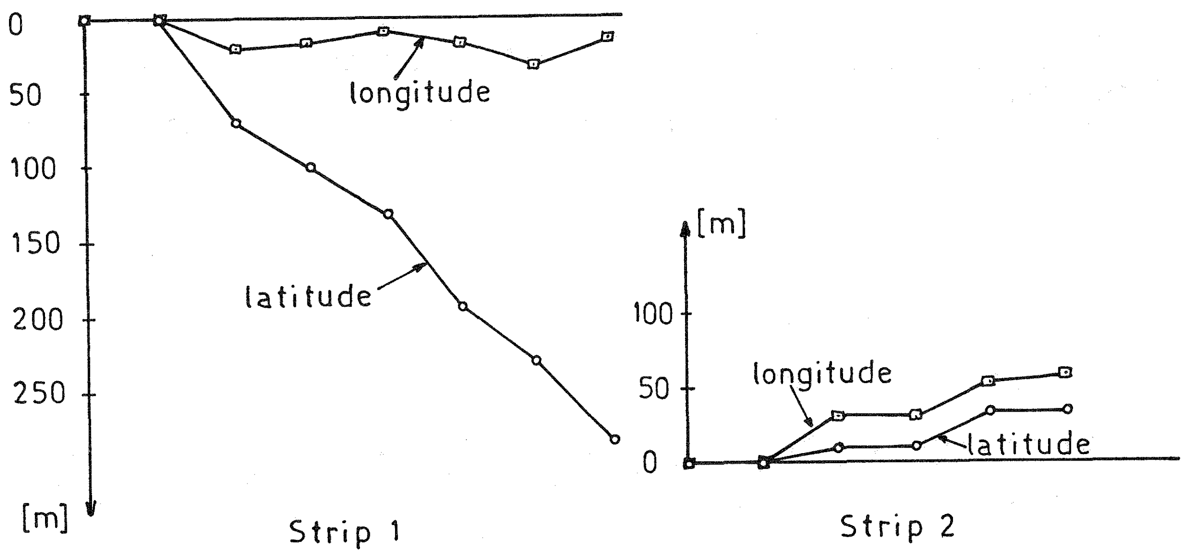

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1) A block of 3 strip of 10 photographs (9 models) each with ground control only at the beginning of the strips(fig. 5). In this case the average standard deviations (in microns in photoscale) computed from 72 check points are:

$$\sigma_x = 123\mu ; \quad \sigma_y = 72\mu ; \quad \sigma_z = 38\mu$$

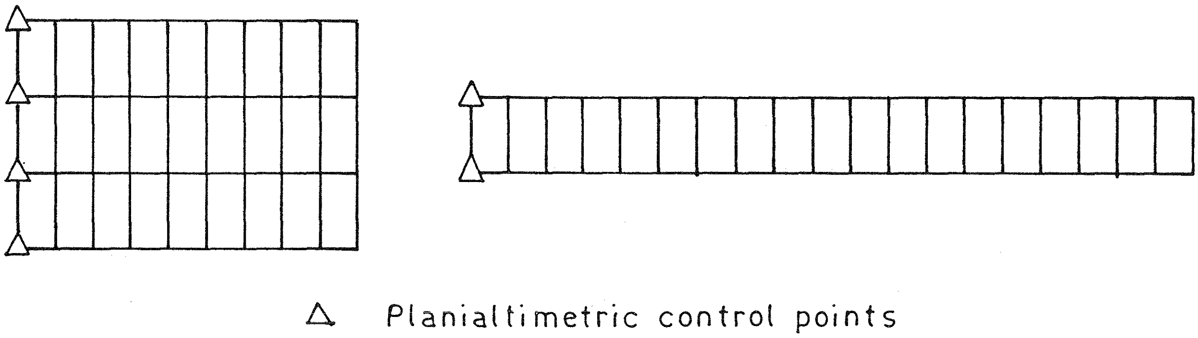

fig. 5

The accuracy of Z coordinate can be considered as very good. The lower accuracy in X and Y can be substantially improved with planimetric ground control at the corners of the block.

2) A strip of 20 photographs (19 models) with ground control only at the beginning (fig. 5). In this case the altimetric accuracy is still very good:

$$\sigma_z = 58\mu \text{ (62 check points)}$$

The accuracy in X coordinates (scale error) deteriorates, however, sistematically. Thus, for long strips it will be better to have at least one planimetric ground control at the end.

Another processed example included systematic errors in in photocoordinates as well. Sistematic errors of types indicated by Ebner /5/ were introduced in photocoordinates. The results were also very good, especially in the altimetry.

It is considered that these results are interesting in spite of the fact that resulting errors in ground coordinates are worse than those which can be obtained in a block adjustment with an optimal ground control distribution. In large inaccessible areas, to obtain a precision in altimetry of 1 m from 1: 20000 photography or 2 m from 1: 40000 photography with control only at one side of the area (beginning of the strips) can be a very economical and good solution in many situations.

5. Further tests

The Paraná test is only the beginning of a research project which includes other flights with the same purpose. These flights, two of which have been already flown in the province of Tucumán, were planned to obtain small scale photography. In this way the quality of PICS data will be judged at the most appropriate scale for its use.

Due to unexpected rains in April, the ground work corresponding to the flights flown in Tucumán could not be completed. It is expected, however, that for the KYOTO Congress, some results of these new tests will be presented.

6. Conclusions

The Paraná test, although not complete, shows interesting possibilities of PICS data for aerial triangulation. More research is needed to obtain reliable figures of the real potential of this data.

Large South American countries should encourage this type of research because this technique can offer a very efficient and economical possibility for mapping large and inaccessible regions.

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