EXPERIMENT AND DISCUSSION ON THE METHOD OF BLUNDER LOCATION

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Abstract

A step-by-step method of blunder location is introduced. Some systematic experiments were carried out to that method and other three kinds of conventional location methods, by using different point distribution models that had varying blunders. the results showed that the step-by-step loction method is more precise and credible than others.

1.INTRODUCTION

Recent years much attention had been paid to the blunders in international photogrammetric community.It can be seen from a number of articles published in the 15th International Archives of Photogrammetry and Remote Sensing.

It is well known that during the photogrammetric operations, blunders are inevitable.The existence of blunders not only influences the accuracy of adjustments (such as control points and common points with blunders),but the more important thing is that it makes the results of adjustment unreliable.

According to the discussions of commission III of the 15th Congress of International Society for Photogrammetry and Remote Sensing convened in Brazil,there are two kinds of methods: (1) blunder detection after the least square adjustment,for example, the famous "Data snooping" [1] and Danish Method [2] etc.;(2) alternation of method of adjustment.It is generally considered that least square adjustment can not treat observation blunders correctly,because least square method tends to distribute blunders to other correct observations,what adds difficulty to blunder detection and location.It is,therefore,necessary to select new method of adjustment,such as adjustment method of $\Sigma|V|\rightarrow min$,which is better than least squares $\Sigma|VV|\rightarrow min$ in blunder location .this paper deals mainly with some experiments and approaches by the former method.

In addition,the purpose of these experiments is to serach for method which can locate blunders accurately.In the process of experiments two aspects were considered:one was the rate of blunder location,the other was a probability of rejecting truch (type I error).In the papers on blunder detection and location presented at home and abroad before,only rate of blunder location was considered,generally,thus its practicability has to be reduced,as a probability of rejecting truch is much larger,which will cause many unneccessary repetitions.

The experiments described in this paper were carried out in the process of relative orientation adjustment.

2.ARTIFICIAL SIMULATED EXPERIMENTAL DATA

3 sets of simulated Data of different point layout are prepared. They are used for models with 9 points,10 points and 12 points respectively,point distributions are shown in Figure 1,2,3.

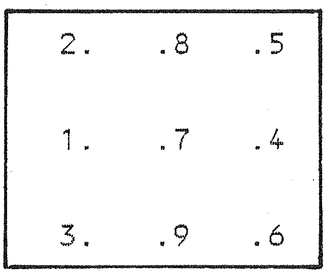

Fig.1

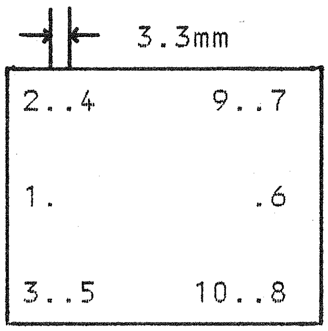

Fig.2

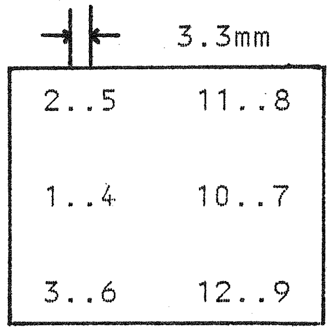

Fig.3

Each set of data consists of 8 strips,with blunder of 5 σ_0 ,8 σ_0 , 11 σ_0 ,14 σ_0 ,17 σ_0 ,20 σ_0 ,23 σ_0 ,and 26 σ_0 respectively,observational random error is 10 um.The total amount of models are 72,80 and 96 respectively.Each model has one point with blunder which spreads evenly at individual point location.

Besides,additional preparation of 3 sets of data (the same as above but without blunders) has been made,the difference lies in observational random errors in strips e.g. 5.0,6.5,8.0,9.5,11.0, 12.5,14.0 and 15.5 um respectively.

3.THE EXPERIMENTS ON THREE CONVENTIONAL BLUNDER LOCATION METHODS

(1) "Data Snooping" method

The theory developed by Professor Baarda of Netherlands, is a rigorous from the point of view of mathematical statistics, theory of blunder and deduced on the basis of least square adjustment.The core of this method is the selection of a statistic

$$W_i = |V_i| / \sigma_{vi} = |V_i| / (\sigma_0 \sqrt{q_{ii}}) \sim N(0,1) \qquad (1)$$

where v_i=correction of observations
σ_0=unit weight in mean square deviation
σ_{vi}=mean square deviation of correction
q_{ii}=the ith element on main diagonal for matrix Qvv of correction weight coefficients

to justify whether blunder is presented or not.In this method research on minimal blundr value (inner reliability) which is possible to be found is made.Thus we have

$$\delta'_{0li} = \delta_0 / \sqrt{q_{ii} P_i} \qquad (2)$$

where P_i=weight of i^{th} observation
δ_0=a constant,in the case when level of significance=0.001, the rate of detection $1-\beta$=0.80,δ_0=4.1

The scholars in the word apply this method to blunder location,that is,after convergence of adjustment,compute statistic W_i and inner reliability δ'_{oli} ,using this as critical value , a judgement can be made:

$$W_i > \delta'_{oli} \quad (3)$$

Assume that the expression (3) is true,then it may be considered that the observation contains blunder.Our experiments are carried out by the same method,only a transformation is made to expression (3).

According to expression (1) and (2),an integer $\sqrt{q_{ii}}$ is multiplied to both sides of expression (3),thus obtain

$$|V_i| / \sigma_o = W_i' > \delta''_{oli} = \delta_o / \sqrt{P_i} \quad (3a)$$

By comparison expression (3a) with expression (3),although there exists only a small change,but so far as computation is concerned, this cna reduce a large amount of work,because computation of cubersome matrix Qvv can thus be avoided.

Results of experiments see Table 1 and 2.

Table 1

date \ No. of points for detection \ strip	5 σ_o	8 σ_o	11 σ_o	14 σ_o	17 σ_o	20 σ_o	23 σ_o	26 σ_o	Ratio of location (%)
1	0	3	5	5	6	7	9	9	61.1
2	1	3	7	10	10	10	10	10	76.2
3	1	6	9	11	12	12	12	12	78.1

(2) Danish method

Danish method is usually referred to as weight function method.

Table 2

date \ No. of point for detection \ strip	5.0	6.5	8.0	9.5	11.0	12.5	14.0	15.5	a probability of rejecting truth (%)
1	0	0	0	1	0	2	7	6	2.47
2	0	0	0	1	0	3	11	10	3.12
3	0	0	0	0	6	11	13	27	4.95

The deduction of this theory is based on maximum likelihood method. After adjustment the absolute values correction forobservation with blunders are larger than those for normal observations, therefore, select a decrease function with $|vi|$ as a variable to define weight Pi, the larger the $|vi|$, the smaller the given weight will be; the smaller the given weight, the more should blunders be presented on $|vi|$. Finally the blunder can be located (see references 2.and 3.).

It is recommended in this paper that a method to combine weight function with "data snooping" should be adopted, that is, in the process of iterative adjustment, weight function method is to be used so as to change weight of observations, after convergence of adjustment is made, compute Wi' and δ''_{oli}, and determine whether they are blunders by expression (3a). The measure taken is rational and efficient, because weight function can distinguish very well between points Vi with blunders and those without blunders, and "data snooping" method can provide us with accurate judgement, furthermore, theory of "data snooping" does not require all the observations having equal accuracy. Hence, the adjustment after alternation of weight, is still strictly in accord with the theory of "data snooping".

Weight function recommended by Danish Geodetic Research Institute is (see reference 2.):

$$f(\lambda_i)=\begin{cases}1 & \lambda_i<C \\ \exp(-0.05\lambda_i^{4.4}) & \lambda_i>C \quad \text{the first to 3rd iterations} \\ \exp(-0.05\lambda_i^{3.0}) & \lambda_i>C \quad \text{after 4th iteration}\end{cases} \tag{4}$$

$$Pa+1=Paf(\lambda_i) \tag{5}$$

where $$\lambda_i = |vi|\sqrt{Po}\,/Mo \tag{6}$$

Vi=correction of observation
Po=original weight of observation
Mo=unit weight in mean square deviation of observations
C=a constant, usually adopted as 3
a=iterative ordinal number, to be 1,2,...

It is found that the above mentioned weight functions have two deficiencies: firstly, when $\lambda_i \geqslant c$, function $f(\lambda_i)$ will decrease rapidly to zero; when number of point $\lambda_i \geqslant c$ increases, it is liable to make normal equation singular, and no solution can be reached; secondly, using the expression (5) to determine weight, it is impossible to let weight of observation with declined $|vi|$ back to the original, for example, an observation after first iteration, $\lambda_i \geqslant c$, the weight becomes smaller. When second iteration is made, although $\lambda_i<c$, but the weight is still very small. After the iteration procedure was repeated many times, the observations with declined weights increase continuously, it also tends to make normal equation unsoluble. Therefore, in this experiment some modifications to weight function are made:

$$P=\begin{cases}Po & \lambda_i<c \text{ or } a<2 \\ Po\exp(-0.05\lambda_i^{3.0}) & \lambda_i>c \text{ and } a>2\end{cases} \tag{7}$$

Where adopted value for c is 3. Experimental results are shown in Table 3 and 4.

Table 3

strip / No. of points for detection / data	5 σ_0	8 σ_0	11 σ_0	14 σ_0	17 σ_0	20 σ_0	23 σ_0	26 σ_0	location rate (%)
1	1	5	7	8	8	9	9	9	77.8
2	3	8	9	10	10	10	10	10	87.5
3	6	9	12	12	12	12	12	12	90.6

Table 4

strip / No. of points for detection / data	5.0	6.5	8.0	9.5	11.0	12.5	14.0	15.5	probability of rejecting truth (%)
1	0	0	1	1	8	5	12	9	5.56
2	0	0	1	6	2	9	19	15	6.50
3	0	1	3	8	14	17	26	38	9.29

(3) Weight function recommanded by document [3]

The principle of the method is similar to that of Danish Method, only the selected definite weight function is different. Definite weight function recommanded by document[3] is:

$$\lambda_i = |v_i| / \sigma_0 \qquad (8)$$

$$P_i = \begin{cases} P_o & \lambda_i \leqslant c \\ P_o / \lambda_i^{(IT+1)} & \lambda_i > c \end{cases} \qquad (9)$$

where vi = correction of i observation
σ_0 = standard deviation
IT = iterative ordinal number, computed from the first conventional adjustment
c = a constant, c =(IT + 1) / 2
Pi = weight of i observation
Po = original weight of i observation

Experimental results see Table 5 and 6

Table 5

strip / No. of points for detection / data	5 σ_0	8 σ_0	11 σ_0	14 σ_0	17 σ_0	20 σ_0	23 σ_0	26 σ_0	location rate (%)
1	5	7	8	8	9	9	9	9	88.9
2	7	10	10	10	10	10	10	10	96.2
3	9	12	12	12	12	12	12	12	96.9

Table 6

strip / No. of points for detection / data	5.0	6.5	8.0	9.5	11.0	12.5	14.0	15.5	probablilty of rejecting truth (%)
1	0	1	3	3	10	8	11	15	7.87
2	1	1	5	9	6	11	20	18	8.88
3	0	1	5	12	12	23	35	41	11.28

(4) Brief summary on 3 kinds of blunder location method

a.The method to combine weight function with "data snooping" is very effective, its effect is much higher than that of "data snooping".
b.From the point of location,the third method is the best, as to data with 10 points and 12 points,blunders of more than 8 times σ_0 can be located.
c.Generally a probability of rejecting truth is increasing while location rate increases, It may be seen from the results that if only location rate is taken into consideration and disregaring probability of rejecting truth, in operations it is bound to cause a number of unnecessary repetition of work.
d. A probability of rejecting truth is concerned with random observational error,generally it is increasing while random observational error increases. Therefore, random observational error should be reduced as far as possible
e. Location rate has relation with layout of points, and the sets of points are more effective than individual one. To relect sets of points at four corners of a model is a more economical and beneficial way.

4.STEP-BY-STEP BLUNDER LOCATION METHOD

It can be seen from the results made by using three conven--tional methods, that none of them is said to be accurate,especi--ally, a probability of rejecting truth is too large. The paper recommends a step-by-step blunder location method which divides location process into three steps, and accordiog to purpose of the step,different weight functions and detection procedures are selected.

In the first step,purpose of detection is to locate large blunders, so weight function being selected is the one not too sensitive to blunders.A suggested weight function is:

$$P_i = \begin{cases} P_o & \hat{\lambda}_i \leqslant c \\ P_o/\hat{\lambda}_i^{(6-IT)} & \hat{\lambda}_i > c \end{cases} \qquad (10)$$

where $\hat{\lambda}_i = |V_i| / \hat{\sigma}_0$ (11)

C=a constant,the value to be used is 2.5
IT=iterative ordinal number,if IT>3,then IT=3
$\hat{\sigma}_0$=estimate value for unit weight in mean square deviation of observations

Where computation of $\hat{\lambda}_i$ is made by $\hat{\sigma}_0$ instead of σ_0 ,the purpose is to decrease $\hat{\lambda}_i$ .because at the time of first and second iterations,Vi as influenced by original valuation of unknown parameters tends to be large,for example,if Vi and σ_0 are used to define weights,they are likely to be influenced by systematic errors,so as to let weights of many points become smaller,and cause blunder detection inaccurate. When $\hat{\lambda}_i$ >C (generally it is influenced by blunders),in order to reduce its weight rapidily, weight function to be selected is exponential which increases with iteration times and decreases with orders.As $\hat{\lambda}_i$ is computed by $\hat{\sigma}_0$,it is not large during the first and second iterations ($\hat{\lambda}_i$ is usually not larger than 3),at this time the use of higher order can reduce its weight rapidily,to decrease influence of blunders as soon as possible.

Experiments have shown that the weight function is only to be used to locate large blunders and some blunders of point location which are sensitive to it.

In second step,the purpose is to search for whether adjustment systems have blunders or not.When adjustment system is affected by blunders,it is liable to have certain influence over an accuracy (see Table 7),consequently, after convergence,as to estimated values of unit weight in mean square deviation of observations,a F test should be carried out,and to see whether blunders can be identified.

F test forunla is

$$\hat{\sigma}_0^2 / \sigma_0^2 > F(r, \infty, \alpha) \quad (12)$$

where $\hat{\sigma}_0$ =estimate value of unit weight in mean square deviation
σ_0 =true value of unit weight in mean square deviation
r =redundant of observations
α =level of significance, in the experiment =0.01

Table 7

data \ average accuracy \ strip	5 σ_0	8 σ_0	11 σ_0	14 σ_0	17 σ_0	20 σ_0	23 σ_0	26 σ_0
1	15.3	21.5	27.9	34.4	40.9	47.5	54.2	60.8
2	14.9	20.2	25.8	31.6	37.4	43.3	49.2	55.1
3	13.5	18.0	22.9	28.0	33.2	38.4	43.7	49.0

remarks: average accuracy in Table 7 is referred to as average value for estimate value of unit weight in relative orientation of individual strip models (unit: um),true value of unit weight is 10 um.

Third step,is to locate small blunders in adjustment system. When results of F test (12) is true,this step should be taken, otherwise no further adjustment is needed.

Weight function selected for the third step is

$$P_i = \begin{cases} P_o & \lambda_i \leqslant C \\ P_o / \lambda_i^{(6-IT)} & \lambda_i > C \end{cases} \qquad (13)$$

where $\lambda_i = |v_i| / \sigma_o$

C= a constant, C = (IT+1) / 2
IT = iterative ordinal number, compute from F test
σ_o = true value of unit weight in mean square deviation for observations

Results of step-by-step blunder location method see Table 8.

Table 8

data \ No. of points for detection \ strip	5 σ_o	8 σ_o	11 σ_o	14 σ_o	17 σ_o	20 σ_o	23 σ_o	26 σ_o	location rate (%)
1	3	7	8	8	9	9	9	9	86.1
2	4	9	10	10	10	10	10	10	91.2
3	5	10	12	12	12	12	12	12	90.6

Probabilities of rejecting truth are all zero.

By comparison between step-by-step blunder location method and the previous best one, it can be seen that there is a small decrease in detection rate,this means that only small blunders (such as 5 σ_o ,8 σ_o)have low location rate, but accuracy is considerably improved. Probabilities of rejecting truth for 3 sets of data are all zero.

Table 9 and 10 are results of the step-by-step blunder location method, when models including 2 or 3 blunders with the same size are presented.

Table 9

No. of points for data detection \ strip	5	8	11	14	17	20	23	26	location rate (%)
1	6	12	13	13	13	13	13	13	66.7
2	9	17	19	19	19	19	19	19	87.5
3	15	20	23	23	23	23	24	24	91.5

remarks:
there are results for models including more than two blunders

Table 10

No. of points for data detection \ strip	5	8	11	14	17	20	23	26	location rate (%)
1	9	18	19	19	19	19	19	19	65.3
2	9	18	20	22	22	23	22	22	65.8
3	20	28	29	30	35	35	35	36	86.1

Remark:There are results for models including more than 3 blunders.

From the results of experiments it can be seen that the location rate for step-by-step blunder location method is very high.When sets of points and blunders larger than 11 6. are taken,nearly all such kind of blunders can be located.In addition,the more redundant observations in adjustment system,the blunders are easier located; the more blunders of adjustment system,the more difficult will be.

In general,a conclusion can be drawn that step-by-step blunder location method is the most accurate,reliable and very effective one.

References

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