PROCEDURES OPTIMISATION IN THE QUALITY SYSTEM

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Summary

The results of procedurea optimisation in the activity of "Gino Cassinis" Laboratory of Politecnico of Milan are discribed in this report. The laboratory works into Politecnico of Milan's Quality Sistem for the determination of instrumental standard deviation of teodolites, diastimeters and levels.

1- Introduction

This Memorial Meeting organized with sensibility by prof. Mussio in memory of Prof. Cunietti gives us the possibility to make some considerations on the activities that the Survey Department of DIIAR (once "Istituto di Topografia, Fotogrammetria e Geofisica" headed for many years by prof. Cunietti) is carring on.
The activity related to the Quality System started and had its impulse with prof. Cunietti who had a deep knowledge of the topographic instruments.
We have to remember that prof. Cunietti suggested to name our Quality System laboratory after prof. Gino Cassinis (ISPRS President, Rector of the TU of Milano and Major of the same city), our distinguished predecessor at the Topography Institute as principle of the chair later occupied by prof. Cunietti.
After this right and opportune introduction, we want to observe that one of the prerogatives of the System is the constant check of the plannings as well as the obtained results. That is to say that the application of operative methods needs continuous checks.
These checks that are made every half-year often lead to the introduction of method variations. These variations can be defined as optimisation interventions.
We want to illustrate the modification about the taratura of the teodolites until now carried out with another procedure that was dated before July 1997, when the "Gino Cassinis" Quality System Laboratory began its activities.

2 - Procedures

The measures and calculation procedures have been studied so that the errors have no influence on the search of precision.
Tests results are due to casual influences that are difficult to analyse: the causes derive from all the instrument parts, from the operator and are heavily influenced by metereological and illumination conditions.
We chose to work on the ground and our suggestion is to work in normal, not in extreme conditions.
Working in different conditions it is possible to know metereological condition influences: This isn't a laboratory goal; so the reccomendation is to work during normal (not extreme) condition.
Using the same procedures with a significant number of instruments of the same model (minimum 4) it is possible to define the characteristics of that instrument model. Also this isn't a goal of laboratory activity. Besides if is possible to make this evaluation using all the reports result from our activity; in this case the results dipend also from the rectified conditions of instruments that arrive to the laboratory.
The DIN 18723 assumes the standard deviation to represent the instrument precision. For this reason, different series of l_j measures are carried out in relation to the kind of instrument; every **j** serie is characterized by a certain number of $\mathbf{n_j}$ values referred to the same largeness (considered undipendent).
The simplest example is the settling of the standard deviation of teodolites: once fixed the instrument, we define 5 aims **sc** in a suitable place and distance.
The measure operation can be repeated with the strata method, in a quite short time and anyway in the same conditions. Every statum **str** is made by 5 lectures that determine 4 angles. Since we don't know before the angle that we are going to measure, to create a ripetition it is necessary to make at least two strata; the number of indipendent measures $\mathbf{n_j}$ that we see is:

$$n_j = (str - 1) \cdot (sc - 1)$$

This number is made by a serie that has in itself the characteristics of repetition but this is up to the operator and the weather conditions. Mean square errors analisys of the measured values compared with mean value constitutes a dispersion index that is characteristic of the whole instrument, operator and ambience.
This formula defines the difference of the value:

$$v_{ij} = \left(\bar{l}_j - l_{ij}\right)$$

where $\bar{l}_j$ is the medium of **l** values of **j** serie.
Of course it results:

$$vv_j = \sum_{i=1}^{n_i} v_{ij}^2$$

It is possible to make another serie in a different time in order to create a second datum with the same instrument but with another operator and different weather conditions. The influence of the operator and the environment is considered "accidental" in the comparison of the two series. Statistic theory is able to estimate instrumental standard deviation in operative conditions, using the addition of different series square errors.

The series number is indicated by μ.

The **f** value, number of the freedom grades of the operation, that is of the indipendent measures, can be obtained with the multiplication of the number of the indipendent measures of every stratum with the number of the strata:

$$f = \mu \cdot n_j$$

The standard deviation **s**, referred to the measures made in the different series, is determined by the relation:

$$s = \sqrt{\frac{\sum_{j=1}^{\mu} vv_j}{f}}$$

This value is more or less different from de teorethical value σ in order of the mesuraments number really made. The statistic methods make us determine an interval so that we can think that σ is contained with a certain probability. We can determine that standard deviation value that corresponds to the probability P=95% (as indicated in DIN 18723) simply multipling the value **s** with a coefficient χ defined in function of **f**:

$$\sigma = s \cdot \chi$$

Each procedure used in laboratory makes reference at this teoretical approach, with different forms according to the measurament kind: azimut, zenit, distances or difference of level.

3 - Optimisation tests

The aim of the optimisation tests is to verify how the standard instrumental deviation varies in function of the measures redundancy. When the redundancy varies, the coefficient χ, which is to be considered a pejorative coefficient, also varies. It increases standard deviation according with the measures number, to consider the test significativity. Significativity increases with the number of indipendente measures.

From one side one tends to make a high number of measures to give significance to the value (χ below); on the other one tends to reduce the number of measures to reduce the time (and the cost) for any determination (high χ).

We decided to perform some tests to verify these values and we used WILD TC2000 teodolite. On the traditional survey scheme, we took many measures. On the 5 signals we made 3 series of 4 strata.

The 3 series have been carried out by 3 different able operators, in good weather conditions (fresh and with covered sky).

In table 1 we indicated the number of series, the number of strata, the number of signals, the **s** value, the number of free grades **f** (the number of indipendent determinations), the χ factor that correspond to 95% of probability, the value σ to be associated with the estimed population in the limited number of tests.

It is easy to note that if we increase the measures number we modify the value **s** (25% more), while the σ value changes only for 10%. When the strata number increases we have different types of errors that increase the dispersion of the tested values.

The evaluations of the zenital angles, tested together with the azimut ones and described in table 2, are instead different.

Minimum σ isn't obtained during the test with the biggest number of freedom; that is synonym of some outliers into measured values. Notwithstanding this, standard deviation isn't substantially modified with the lower measure number.

We considered an average value of about 14 minutes per every serie corresponding to a complete reposition of the instrument, to a change of operator and, if possible, to a work day. Every stratum corresponds to 4 minutes. Every display operation (not the old teodolites) needs about 1 minute; every point needs 2 minutes for the two testings.

Regarding these data we can estimate the measure time for the six examples above: 2h 56', 2h 33', 1h 58', 1h 30', 1h 33' and 1h 2'. The relation between time and operations is very difference with the conditions choosed. The laboratory follows now the fourth procedure of table 1 (that is 2 series of 3 strata with 5 signals) for about 1h 30' work.

4 - Conclusions

It is possible to project a reduction of the number of measures to perform for every laboratory test on behalf of the results above mentioned. We think anyway it is correct not to discend more than **f** =10.

The real casuality of the population distribution remains a problem.This changes a lot the results. To avoid this problem the operators have to work very carefully and they have to be very precise.

It's possible to identify some outliers comparing meausures with high accuracy reference values. A real time check wuold be possible working into a references polygon, known with high accuracy. Each measure must be different from true value less then the instrument estimated (or nominal) standard deviation.

Certainly in actual laboratory activity it is possible reduces the number of indipendent measures surveyed for teodolites and diastimeters, with a significant reduction of measuring times.

5 Bibliography

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n° serie	n° strata	n° signal	s	f	χ	σ
3	4	5	0.00029	36	1.24	0.00036
3	4	4	0.00030	27	1.29	0.00039
2	4	5	0.00030	24	1.32	0.00039
2	3	5	0.00029	16	1.42	0.00041
3	2	5	0.00026	12	1.52	0.00040
2	2	5	0.00024	8	1.71	0.00041

table 1 - the result of the optimisation test in the measure of the azimut angles

n° serie	n° strati	n° segnali	s	f	χ	σ
3	4	5	0.00033	45	1.21	0.00040
3	4	4	0.00029	36	1.24	0.00036
2	4	5	0.00025	30	1.27	0.00032
2	3	5	0.00024	20	1.36	0.00033
3	2	5	0.00027	15	1.44	0.00039
2	2	5	0.00024	10	1.59	0.00038

table 2- the result of the optimisation test in the measure of the zenital angles.