QUALITY CONTROL PROCEDURE FOR PHOTOGRAMMETRIC DIGITAL MAPPING

R.J. Ackermann

International Institute for Aerospace Surveys and Earth Sciences (ITC)
P.O. Box 6, 7500 AA ENSCHEDE, The Netherlands
Tel. +31-53-4874392, Fax +31-53-4874335

A. Eslami Rad
National Cartographic Center of Iran

Commission IV, Working Group 1

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ABSTRACT :

Quality assurance has become a major concern in a digital mapping environment and quality control procedures have been implemented in photogrammetric production lines by many mapping organizations. There is yet some uncertainty about procedures, quality parameters, sampling and statistical methods to be applied due to lack of standards. In the present paper an attempt is made to describe a quality control system which can be applied to photogrammetric feature extraction. Quality control covers all process involved in the creation of a spatial database where data are mainly collected by photogrammetric technique. There is generally agreement on the main quality components like positional accuracy, attribute accuracy, completeness, logical consistency, lineage and time. Not all of them are equally important for quality assessment; this paper will focus on positional accuracy, semantic accuracy and completeness after data collection since they can be easily assessed through statistical quality control procedures. The most reliable method for final quality assessment is the field control; it is also the most expensive. For photogrammetric control the original photographs are generally used and therefore this method has its limitations; however it provides useful information for the subsequent field completion. Quality reporting is of prime interest to the user; part of the information can be transfered into the database in the form of a separate quality layer.

1. INTRODUCTION

Quality control can be defined as "the operational techniques and activities that are used to fulfil requirements for quality" (ISO). Quality remains a vague concept, hard to define and sometimes difficult to measure. Surveyors and photogrammetrists have always been concerned about the accuracy of their observations.

Today, the concept of quality has been put into a broader perspective and the development of GIS requires a better quality management. Technological development and new requirements from the users had a strong impact on quality control and quality assurance. There are six fundamental quality components of spatial data (Thapa, Bossler, 1992) :

- lineage
- positional accuracy
- attribute accuracy
- completeness
- logical consistency
- temporal accuracy

Lineage describes the source material from which the data were derived (photographs, control points) and the methods used for the production of the spatial data. Positional accuracy can be assessed by comparing a photogrammetric data set to an independant reference data set of higher accuracy (e.g. GPS data or field survey data).

The errors we have to deal with are of three types:

- gross errors and blunders : they do not belong to the sample of observations and must be eliminated.
- random errors: they are present in any set of observations and their characteristics are well known, provided that the sample size is sufficiently large (n=50)
- systematic errors : they occur because of many imperfections through the various processes. Systematic errors introduce a bias in the observations and affect the accuracy.

Extensive field control carried out at IGN (France) has shown important local systematic errors (Grussenmeyer, 1994)

Classification accuracy tests need to be designed in order to judge whether a proportion of misclassification in a given sample is acceptable or not.

A binomial distribution can be used for testing the classification accuracy of topographic features. The acceptance sampling method deals with the optimum number of ground samples N and an allowable number X of misclassifications (Ginervan, 1979).

This method gives an overall estimate of misclassification accuracy but does not differentiate between omission errors (excluded from a class) and commission errors (included in a class). Therefore,

commission errors (included in a class). Therefore, the misclassification matrix seems to be a better tool. Completeness will report on missing features due to inattention of the operator or obstructed objects. For photogrammetric control the superimposition technique is the most reliable. Completeness is checked based on specifications with additional rules such a minimum length, minimum width, minimum area, etc. Features or areas where field completeness is required can be given a special code during data collection, facilitating in this way the field operations. In addition, clear specifications are required for minimum completeness percentage, as well as producer and consumer risk.
Logical consistency can only be checked to some extent with available CAD software. More powerful systems where data collection takes place within a GIS environment offer more possibilities for on-line checking. Temporal accuracy refers to the currency of data. This type of information may be critical for certain classes of features, subject to rapid changes and for applications requiring current data.

2. QUALITY CONTROL AND PHOTOGRAMMETRIC FEATURE EXTRACTION

Different strategies may be applied to ensure quality of a final product. The choice is between the final verification strategy at the end of a production line and the "zero defect strategy" where all the processes of a production line are controlled. This is obviously a better and more economic approach as it may lead to zero defect production; for this purpose, a quality system is required. It can be defined as a "documented organizational structure consisting of processes, procedures, resources and techniques with the objective to assure quality in that organization" (ISO).

2.1 Quality control in a production line

The "zero defect strategy" can be sudivided into three levels (Eslami, 1995):

- Level 1 is called the process control which continuously monitors the quality of the various aspects of data production and handling process. Decision rules need to be developed for each process based on quality parameters and quality standards.
- Level 2 consists of the data editing process in which every operation directly affects the quality of the data.It is also a critical phase since many tasks are performed either in semi-automatic or automatic mode.
- Level 3 contains a monitoring system based on an acceptance sampling technique. Decision rules are required in order to accept or reject a work lot of output (e.g. maps)

2.2 Process control procedure

A control procedure starts by extracting values of relevant quality parameters which give an indication of the integrity of performance in a particular process. For the orientation process well established accuracy standards are available for interior, relative and absolute orientation (e.g. maximum residuals errors in X, Y and Z). If a computed value is found to be acceptable, one proceeds to the next process, otherwise corrective actions need to be initiated (figure 1).

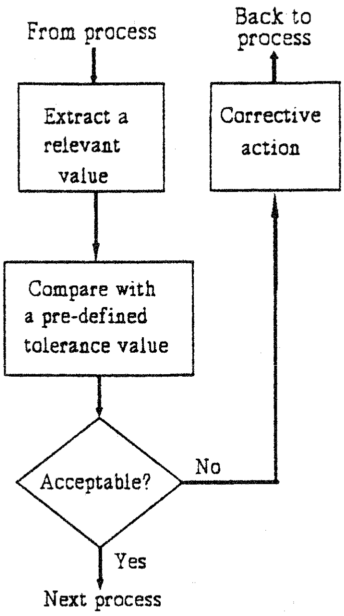


Figure 1: Process control procedure

A control chart is often used in production lines to detect deterioration of quality characteristics and to forestall failures of a process. It is a graphical display of a quality characteristic that has been measured and computed from a sample versus the sample number or time.
As long as the graph is located between lower and upper control limits, the process is in control. A non-random pattern in this chart may be taken as an evidence of assignable cause (e.g. large mean Y-parallax on a particular instrument).

2.3 Photogrammetric feature extraction: processes and products

A photogrammetric production line can be subdivided into 6 to 8 processes, depending on the type of product to be delivered (e.g. spatial data, DTM, orthophoto). For each process and the derived product, a quality control procedure needs to be developed.
The quality of a product can be described by a certain number of measurable parameters, whose values will compared to given standards
(figure 3).

2.4 Quality parameters and standards

In the past, quality control strongly emphasized the propagation. Field check of the end product often reveals large local systematic errors. These errors have their roots in the long chain of processes. The question which arises here is whether a better control of the various quality parameters could provide an explanation of these systematic errors and whether eventually it could lead to corrective actions or at least predict in which model area field control is necessary. For this purpose, a total quality factor can be computed for each model, summing up the quality factors of the individual products (e.g. photos, control points, etc.) :

$$Q\ (\text{model}) = (Q1 + Q2 + ...Qn)/n$$

Qi : expressed in percentages

It is expected that quality information at feature level and model level will support efficiently the field completion process.

Some of the quality parameters and standards are summarised in figure 2.

3. METHODOLOGIE FOR QUALITY CONTROL OF A PHOTOGRAMMETRIC DATA SET

A photogrammetric control process has to be applied to the new data set before proceeding to the editing phase. The following quality components will be assessed: positional (relative) accuracy, classification accuracy and completeness. Some quality attributes are normally present in the data set at feature level in the form of reliability codes, indicating how good features could be identified and measured. A sample of check points must be created by an independent process of higher accuracy: for this purpose an analytical plotter can be used. A reliable checking of completeness requires a superimpoition system. If larger scale photographs are not available, the same photographs will be used for feature extraction and control measurements.

3.1 Positional accuracy

The various classes of features are not homogeneous in terms of accuracy; therefore it can be recommended to group features in accuracy classes :

e.g. ac1 : road, railway, canal,
ac2 : building
ac3 : vegetation boundary

For point features and buildings, it is easy to identify homologous check points ; it is more difficult if not impossible to identify such points on linear features like roads, vegetation boundaries etc.

An interesting method has been developed at IGN-Paris, based on the Hausdorff distance which allows the evaluation of planimetric accuracy of a line feature with respect to a reference line (Hottier et al., 1994).

A less rigorous approach consists of taking distances between a sample of check points and a measured line; a RMSE (root mean square error) can be computed and used as a rough accuracy estimator. One can also compute "pseudo" homologous points on a line for a given sample of check points. In this way, the same procedure can be applied, whether one deals with point features or line features. In both cases two sets of homologous points are used: check points (X, Y, Z) and points from the observed data set (X', Y', Z'). RMSEs can be computed for each coordinate separatly, as well as for planimetry :

$$DS_i = \sqrt{DX_i^2 + DY_i^2}$$

$$RMSEP = \sqrt{\frac{\sum DS_i^2}{n}} \qquad \text{(planimetry)}$$

$$RMSEH = \sqrt{\frac{\sum DZ_i^2}{n}} \qquad \text{(height)}$$

DX_i , DY_i , DZ_i are the differences between the two data sets

n : number of check points.

DS_i represents planimetric discrepancies (not errors) in a bivariate normal distribution, while the height discrepancies DZ_i follow a linear normal distribution.

The steps of the sampling and testing procedure can be summarized as follows :

- measure a sample of check points per accuracy class ($n \approx 50$ points)
- compute the mean values of discrepancies:

$$Sx = \frac{\sum DX_i}{n}, \quad Sy = \frac{\sum DY_i}{n}, \quad Sz = \frac{\sum DZ_i}{n}$$

- compute the standard errors σ_x, σ_y, σ_z
- apply a test for significant bias based on Student's t distribution at a 1% significance level
- compute the disrepancies DS_i in planimetry
- detect and eliminate gross errors in planimetry; a robust estimator of the RMSEP can be computed with the help of the median :

$$\widetilde{RMSEP} = 1.201\,\hat{m} \qquad (\hat{m}: \text{median})$$

- compute a tolerance value at a 1% level of significance :

$$T = 2,14\ \widetilde{RMSEP}$$

- recompute $RMSEP = \sqrt{\frac{\sum DS_i^2}{n_1}}$

n1 : new sample size

- apply a test of precision based on a chi-squared distribution (test of goodness of fit).

A similar distribution can be applied for the height discrepancies, keeping in mind that we deal with a normal gaussian distribution.

Experiments carried out on two tests areas show the following results in planimetry :

Project (A) : 46 μm at 1:30,000 photo scale (check points measured from 1:10,000 photo scale).

Project (B) : 53 μm at 1:40,000 photo scale.

Larger values are expected with field checks as can be seen from publications of results by IGN-France (Villet, Leconte, 1995).

3.2 Classification accuracy

No significant misclassifications may show up, unless larger scale photographs are used. The analysis is based on themes like roads, buildings, vegetation; for each theme a separate misclassification matrix will be created.

Here also some statistical testing procedures can be applied.
a_i : (main diagonal): correctly classified features
a_l : (line elements - main diagonal): commission errors, (features erroneously included into a class)
a_c : (column elements - main diagonal) : omission errors (features erroneously excluded from a class)

3.3 Completeness

Checking for completeness and classification goes generally in parallel. The same strategy can be applied: visual inspection according to object classes using superimposition; however the results must be presented separately.

4. QUALITY REPORTING

4.1 Introduction

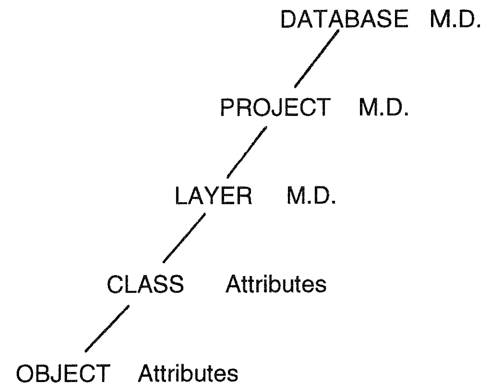
Quality information collected through the various processes need to be filtered and properly stored for easy access and retrieval. There are a number of unanswered questions about quality reporting :

. how much information is required by the user ?
. how to structure and store it ?
. how to display and present it ?

Various attempts for modelling and storing quality information of spatial data can be found in the literature. (Faiz, Boursier, 1994)

4.2 Multi-level approach

The management of quality information is seen from a different perspective by the supplier and by the user of data. This may lead to separate quality models, one which is mainly process-oriented (for the supplier) and one which is data-oriented (for the user). This implies that only part of the quality information has to be transferred to the database.
The basic units for feature extraction are models which will be dissolved in layers of a database; quality information can best be organized in a separate quality layer, using a multi-level approach (figure 3).



(M.D. = Meta Data)

Figure 3: Quality information in a multi-level approach.

Quality information is somewhat heterogeneous and therefore has to be organized partly in the form of meta-data and partly in the form of attributes.
This information is to be stored at various levels :

. Project :	data source camera type photo scale date of flight mission determination of GCPs method of AT method of data collection
. Layer :	lineage (data source, method) logical consistency (after editing) positional accuracy (after field check) classification accuracy (after field check) temporal accuracy
. Class:	model-lay out and model-ID control points data from field check and field completion accuracy (estimated)
. Object :	reliability

4.3 Visualization of quality information.

Quality information can be displayed, graphically or numerically. The more quality attributes that are added at the object level, the more quality analysis can be performed based on quality criteria.
Typical questions which may be of interest for the user are the following:

. which models cover a certain area of interest (defined by a window) and what is the photo scale and the date of the flight mission ?
. in which areas has field check/completion taken place ?
. what is the positional accuracy (in planimetry) of a class of objects ?

This type of question can easily be answered through queries.

PROCESS	PRODUCT	QUALITY PARAMETERS	QUALITY STANDARDS
Flight mission	Photos	Resolving power film shrinkate density sharpness	> 30 Lp/mm < 0.03 - 0.05% 0.2 - 1.5
Field survey	Ground control points	$\sigma_{x,y}$, σ_z (variance-covariance matrix)	$\sigma_{x,y} \approx \sigma_z \approx 0.10$ m
Aerotriangulation	Minor control points	σ_o (plan), $\sigma_{x,y}$ σ_o (height),σ_z (variance-covariance matrix)	$\sigma_o \approx$ 10-20 µm $\sigma_{x,y} \approx 2\,\sigma_o$ (plan) $\sigma_z \approx 2\frac{c}{b}\,\sigma_o$ (height)
Orientation	orientation parameters/ residuals	I.O. fiducials: 4 or 8 mean residual (x, y) max. residual (x, y) scale factors Sx, Sy R.O. points: 6, 10, 12 mean parallax max. parallax A.O. control points mean residual (m) max. residual (m)	 4 (min) 6 µm 10 µm 6 (min) 6 µm 10 µm Plan / Height 4 (min) / 4 (min) 20 µm / 0.2 ‰ Z 33 µm / 0.33 ‰ Z
Data collection (model level)	graphics data attribute data	positional (relative) accuracy MSEP (plan) MSEH (height) (sample of points: ≈ 50) . classification accuracy . completeness	 30-60 µm 0.2 - 0.3 ‰ Z 97-100% 97-100% (depending on feature class)
Field check/ completeness (layer or map sheet level)	additional spatial data	. positional accuracy MSEP (plan) MSEH (height) . classification accuracy . completeness	 60-120 µm 0.3 - 0.5 ‰ Z > 95% > 95%

Figure 3: Products, quality parameters and quality standards

5. CONCLUSION

With the development of GIS the need for quality system has increased. There is now the possibility to document every step of a control procedure ; this may lead to a huge amount of information which may create an extra overhead to the database.
It is also necessary to simplify procedures in order to reduce time and cost. This can be achieved by developing methods and tools which will facilitate the management of quality information.
Finally, more research is required in order to find out whether a continuous quality control leads to a significant quality improvement of the final product and which processes require special attention in order to optimize the whole production line in terms of quality.

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