ON DATA PROCESSING IN PHOTOGRAMMETRY AND CARTOGRAPHY

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ABSTRACT:

Data processing collects several methodologies and procedures able to analyse various kinds of data. Among these, geodesy and related sciences imply traditionally data processing in order to assure precision, accuracy, reliability of the estimates. In fact the above mentioned approach involves generally all physical sciences and particularly the earth sciences. On the other hand, photogrammetry, remote sensing and cartography are moving recently in direction of information technology. This means that data processing requires also new tools, like data compression, signal enhancement, data understanding, hypertexts and multimedia.

1.GALILEO GALILEI

Geodesy and related sciences were born from applied mathematics and astronomy during the 17th century and developed in the following centuries.
Galileo Galilei represented the basic personality at the beginning of this path. He taught applied mathematics and astronomy for 18 years at the University of Padua, since 1592.
The scientific work of Galileo joined very important discoveries in astronomy (exactly in 1597 he wrote to Kepler the first letter in favour of Copernican theory), with interesting jobs of geometry and statistics. Regarding his studies of statistics, they involved some preliminary ideas on the probability (Boyer C.B., 1968) and the first approach to the concept of robustness.
The last one opened the way to the definition of some optimal norms. In particular he described a procedure which introduced the robust estimator, formalised later as least minimum modulus sum.
The path of geodesy and related sciences, from astronomy to geomatics, differed considerably but data processing remained remarkably to characterise these sciences.

2. THE ORIGIN OF THE PATH FROM ASTRONOMY TO GEOMATICS

The astronomers following the Galileo's period needed transfer methodologies and procedures from astronomy to geodesy (Hall A.R., 1963) and started a new discipline. In such a way, accurate measurements, rigorous schema and precise estimates came down from the sky to the earth and defined a particular kind of network: the triangulation.
At the same time and/or immediately after ancient surveying changed, under the influence of geodesy, and became similar to geodesy itself in a closer range.
The figure 2.1 illustrates the flow-chart of the first step of this path in the 17thand 18th centuries.
The 19thcentury gave some formal structures to the physical sciences and, among these, to the earth sciences too. In this frame, physics and chemistry met and grew a set of earth sciences, like geodesy, geophysics, geochemistry, geology, etc. (see figure 2.2).

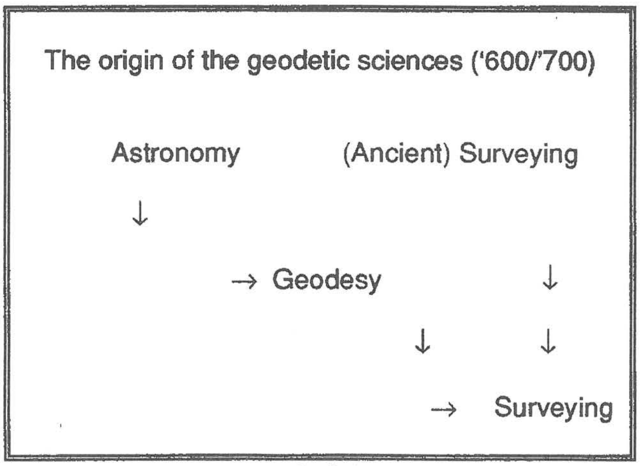

Fig.2.1

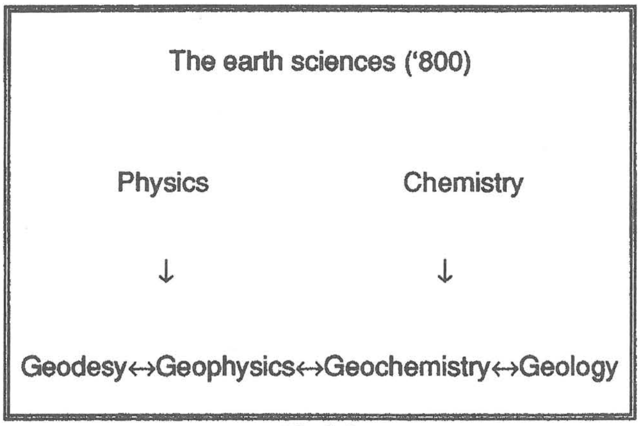

Fig.2.2

3. THE DEVELOPMENT OF THE PATH FROM ASTRONOMY TO GEOMATICS

Some painters and architects of the Middle Age and Renaissance (Giotto, Paolo Uccello, Piero della Francesca, Mantegna, Leonardo da Vinci) discovered the perspective laws and some other methodologies of representation (Gombrich E.H., 1950).
These factors increased the quality of cartography in terms of goodness of map production, being the quality of the data assured by geodesy and surveying.
In the 19th century the meeting between physics and chemistry (Mason S.F., 1956) promoted a new branch of surveying: photogrammetry. It gave improvement to cartography strongly and linked the last one in a positive loop. Indeed photogrammetry supplies much more information, to cartography, than the traditional survey; furthermore photogrammetry itself can be used as a particular kind of representation, which integrates cartography positively.

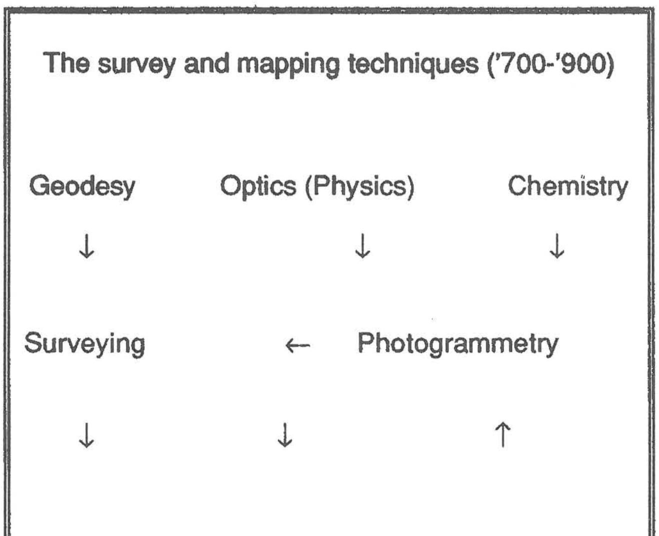

Fig3.1

The figure 3.1 illustrates the flow-chart of the second step of the above mentioned path, which ranges from the 18th to the 20th century, and contains the whole set of the survey and mapping techniques.

4. THE PRESENT TIME OF THE PATH FROM ASTRONOMY TO GEOMATICS

Geodesy and related sciences have found, at the present time, a significant bifurcation.
Indeed, being some parts of them in the field of earth sciences, they are partially moving in the direction of information technology and the speed of this movement appears very high.
On the other hand, the space exploration era, begun since 50's, furnished a new improvement to geodesy. Satellite geodesy permitted to transfer geodetic methods from theory to practice and surveying is now contained in applied geodesy, like a part of it (see figure 4.1).

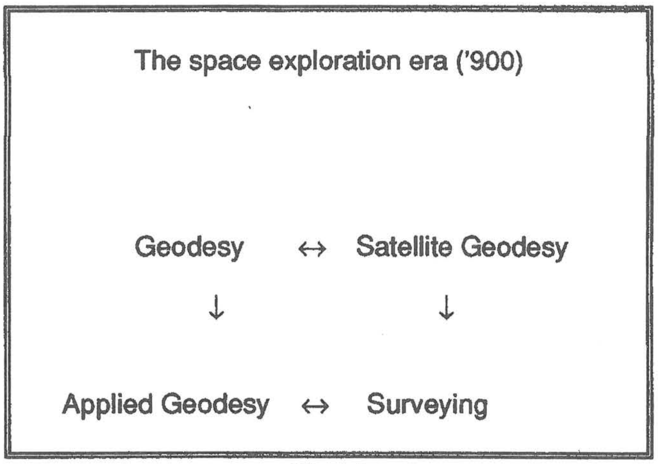

Fig.4.1

At the same time, information technology was born from electronics, it grew very quickly (Wiener, 1948) and involved a lot of different disciplines, like computer sciences, artificial intelligence, robotics, etc.
Photogrammetry and cartography were heavily attracted from information technology.
The meeting between these survey and mapping techniques and the information technology disciplines promoted some new interdisciplinary branches and promises interesting and powerful developments for the future.
Photogrammetry extended its point of view and included the quality analysis by means of remote sensing (remote sensing begun as a product of the space exploration era, but its data supply information in a wider field.).
On the other hand, photogrammetry in close range met machine vision and robotics and furnished, as well as remote sensing, by means of image processing, more information than the traditional one.
Cartography started with some techniques of computer graphics and automatic mapping, but the problems of

data storage and data structure introduced it to GIS/LIS world.

In this frame, the analysis of spatial information, available from images, maps, other types of spatially referenced data, collects a set of methodologies and procedures of data processing, which is called geomatics. The figure 4.2 illustrates the flow-chart of the last step of this path from astronomy to geomatics.

5. ON DATA PROCESSING

Going back to the above mentioned bifurcation, occurred recently between earth sciences and information technology, data processing presents continuity and break lines.

In fact data processing remains remarkably to characterise geodesy and related sciences, being precision, accuracy and reliability of the estimates to be taken into account with due care.

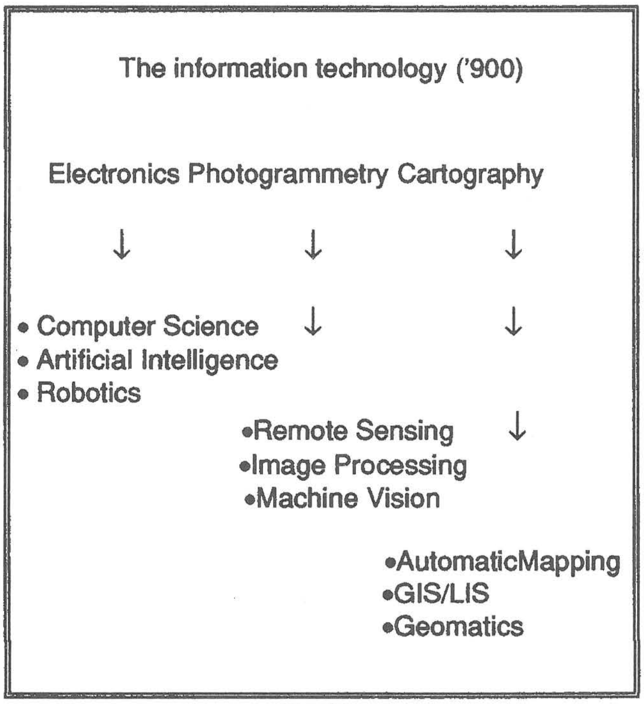

Fig.4.2

On the contrary, data processing requires also new tools, like data compression, signal enhancement, data understanding, hypertexts and multimedia, when the mass of data implies automatic data management and doesn't permit any a priori knowledge.

Although both earth sciences and information technology need both strategies, it seems to be more likely that the first and classical approach involves the set of earth sciences, whilst information technology deals with the second innovative approach. (See figure 5.1).

Therefore the aim of earth sciences is to describe some physical fields in an optimal way; on the contrary the aim of information technology is to produce a pattern recognition in order to achieve preliminary information.

The methodologies and procedures used in the first class of problems concern adjustment, interpolation and approximation, can be refined by optimisation and outlier detection and should be judged by multivariate analysis, under the hypotheses of continuity, independence and normality.

The methodologies and procedures used in the second class of problems concern different kinds of data understanding, like clustering, parsing, vectorization, formalization, etc. On the other hand, the complexity of this approach imposes to perform optimal sampling and outlier detection just at the beginning, in order to define the set of data to be processed : rough data supply very poor information. For these reasons, no hypotheses about the distribution behaviour of the data can be done and a judgement should be acquired by distribution-free inference only.

Data Processing (2000)

Earth Sciences:	Information Technology:
Objectives:	
•Physical Field Description	•Pattern Recognition
Methodologies and Procedures:	
•Adjustment/Interpolation and Approximation	•Optimal Sampling (Data Compression)
•Optimization	•Outlier Detection
•Outlier Detection	•Clustering/Parsing and Vectorization/Formalization (Data Understanding)
•Multivariate Analysis	•Distribution-free Inference

Fig.5.1

6. THE FORMAL STRUCTURE OF THE EARTH SCIENCE OBSERVATIONS

The classical observation equations modelize the linkage between some physical and/or geometrical measurements and point positions and some eventual parameters at that time.

In case the point positions (or the additional parameters) aren't constant during the observation campaign, the variation of the point positions (or the additional parameters) can be modelized by using dynamic equations.

Furthermore because often the campaigns survey dense fields and these fields appear quite regular, it is realistic to model the behaviour of these fields by means of distribution equation.

As well known, it is easy to collect all equations in a functional model, to be linearized if non linear, where all parameters are collected in two classes, respectively with stochastic and non stochastic behaviour.

In addition, a stochastic model links the weight matrix of all the equations with the covariance matrix of the stochastic signal and some a priori information concerning the non stochastic parameters.

Notice that high weights for the dynamic and distribution equations express constraints, whilst low weights for the same equations permit their comparison with the observation equation. Moreover the a priori information are generally quite low, but for the imposition of the reference frame and of some other eventual constraints.

A hybrid norm furnishes the way to obtain the estimators and their covariance matrices.

The stochastic model is linked to the quadratic form: directly in case of least squares and in non linear expression in case of reweighted least squares (e.g. robust estimators).

The figure 6.1 summarises the content of this paragraph.

7. THE FORMAL STRUCTURE OF THE INFORMATION TECHNOLOGY PROCEDURE

As already said, a new class of problems are present in some information technology procedures. The following not exhaustive list shows some examples:

- line following
- transforming spaghetti into topologically consistent structures
- region growing
- establishment of correspondence in geometrical and/or relational matching
- reduction to co-planar graphs
- tasselation of non stellar concave objects
- outcoming of occlusions and layovers
- shape from shading
- phase unwrapping
- spatial analysis and dynamic processes.

Notice that the size of the samples doesn't allow to operate handly; for these reasons, the above mentioned class of problems suffers from the difficulties to operate automatically. Unfortunately this class of problems, often called segmentation, because they are relatively new, they cover many different innovative aspects and they need a new synthesis, not yet done, hasn't a unique, complete and rigorous formal structure.

At present time, many examples are solved in different ways, many researchers suggest different approaches; however the richness of the attempts is still chaotic.

The Bayes' theorem :

$$P(A/B) = \frac{P(A)P(B/A)}{P(B)}$$

requires obviously that the probability of the a posteriori estimates is bigger than the probability of the a priori information. This theorem furnishes a criterium of judgement but it doesn't indicate any suggestion on the way to be followed. Therefore, as already said, more information about very general methodologies and procedures suitable for the information technology is an open problem.

The formal structure of the earth science observations

Observation equation: $\theta = F(P,t)$

Dinamic equation: $P = G\ (t)$

Distribution equation: $g = H(P)$
notice: $g \in G$

Functional model: $\alpha = Ax+Bs+\Delta$

Stocastic model:

$$\begin{bmatrix} kI & 0 & 0 \\ 0 & C_{ss} & 0 \\ 0 & 0 & \sigma_r^2 P^{-1} \end{bmatrix} = Q$$

notice: $k = h$ for the unknown parameters
$= \varepsilon$ for the constrained parameters

Hybrid norm:

$$\Phi = \begin{bmatrix} x^t s^t n^t \end{bmatrix} \Psi(Q^{-1}) \Lambda^t \begin{bmatrix} x \\ s \\ n \end{bmatrix} +$$

$$+\Lambda^t (Ax + Bs + \Delta - n - \alpha_0) = \min$$

notice: $\Psi = I$ least squares
otherwise reweighted l.s.
(e.g., robust estimators)

Fig.6.1

8. REFERENCES

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For the sake of brevity, the most important references, concerning geodesy and related sciences, aren't quoted, because the readers are supposed to be very well acquainted with the specific literature.