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International Association of Geodesy
Special Study Group 4.38, Working Group
"Application of Computers for the Handling
of Geodetic Data".

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Management of Geodetic Data, Status and Prospects 1979.*

Abstract.

Procedures for data entry and validation are reviewed. It is found, that least squares adjustment is generally used for data validation.

Also the establishment and function of geodetic data bases and associated management systems are reviewed, and different data bases are compared. Future problem areas (interrelation with other non-geodetic data bases, optimatization of storage structures, access methods and data models) are pointed out.

1. Introduction

The IAG SSG 4.38 Working Group on " Application of Computers for the Handling of Geodetic Data" was established shortly after the General Assembly in 1975. The group has based its work on Resolution no. 25 adopted at the General Assembly, which recommends exchange of information about the design principles and practical implications of geodetic data bases. However, it was decided to cover the slightly broader subject of the handling or management of geodetic data.

The members of the group include

David Alger, J. Gergen, J. Isner and C.R. Schwarz, all at National Geodetic Survey (NGS), USA.,

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The activity of the group has been concentrated on the study of the design of geodetic data bases and data base management systems (DBMS). The preliminary conclusions of the group have been summarized in two interim reports (Tscherning (1977, 1978)). The group has had one formal meeting during the Second International Symposium on Problems related to the Redefinition of North American Geodetic Networks, in 1978.

Geodetic data are born in the field or at geodetic observatories. The data are screened, and corrected or edited, a process which we in the following will call "data validation". The data will then become part of a geodetic data base, from which data will be extracted for the purpose of carrying out computations. The result of these computations (adjusted coordinates, gravity values, potential differences) will also become a part of the geodetic data base. Finally the data base, with its totality of observations and "results" will assist the users of geodetic data (the surveyors, geophysicists, cartographers) in carrying out their task.

The computer has until recently mainly served as a useful tool when carrying out computations (data reductions, adjustments and data transformations). However, the use of the computer for data handling was soon recognized by geodesists (see e.g. Buck and Tanner, 1972).

Since the General Assembly of IAG in 1975, the use of computers for data handling has had a break-through. Before 1975 the number of paper having as their main topic the handling of geodetic data could be counted on one hand. This present report lists nearly 50 papers published since 1975. Around 20 % of these have been authored or co-authored by members of the working group.

In the following we will give a brief account of all the activities reported in the period 1975-1979. In section 2 we will discuss data handling during field data entry and validation. In section 3 we will treat content, structure and function of geodetic data bases and finally in section 4 we will summarize the observed trends and look at the future problem areas.

2. Field data entry and validation. Data integrity.

2.1. Field data entry.

Geodetic data are born in the field or at geodetic observatories. Observations dating back to the end of the last century are still useful and used in computations. Hence, many geodetic institutions have been engaged in the process of bringing huge volumes of old data from field books into computer readable form, see e.g. (Love and Drosdak, 1978).

Technological developments of instruments have or will eliminate this process of key-punching hand-written data from field books. (This development is discussed e.g. in (Strasser, 1977).) There are different motivations for having data born directly on computer-readable form. These reasons include (1) personnel-savings, (2) elimination or reduction of errors, (3) faster transfer of data to a computer for data validation and processing. However, observation instruments with data recording equipment are still expensive and the equipment is not developed for all types of instruments. Furthermore a solution must (and have) been found for older (otherwise satisfacting working) instruments. Some solutions are:

(a) field data are prepared so that they can be read by an optical reader (Starzmann, 1977)

(b) field data are keyed into a portable general type recording unit (Rüffer et al., 1977)

(c) field data are keyed into a portable mini-computer with data processing and storage capability (and contingently a hard-copy output unit). (Whalen and Balazs, 1976, Beckers et al., 1979, Gubler, 1978).

It is obvious, that solution (c) is to be preferred when it is desired to carry out control computations on the spot.

As pointed out in Safford (1978) control computations in many cases requires the knowledge of additional information e.g. coordinates of fix-points. This necessitates established procedures for the transfer of field data to a main computer facility. This general problem have been solved at NGS by having prepared detailed instructions for the format of input data (Pfeifer, 1978) and by having developed a Terminal Entry Command Language (TENCOL), (Safford, 1978). TENCOL has data validation capabilities as developed by Whiting and Pope (1976).

2.2. Data validation.

When data have been brought into computer readable form, different checks must be made. The most simple checks are for completeness and whether the values are within the range of valid data.

It has long been recognized that further checks can be made using the process of least squares adjustment. The importance, the implementation and the results of this type of validation in connection with a big network adjustment has been discussed by (Isner and Young, 1978, Isner and Alger, 1978, Isner, 1978, and Timmermann, 1978). However, least squares adjustment is used for data validation even for networks of cadastral type, see (Fila and Chamberlain, 1978, Bayerische Landesvermessungsamt, 1978).

In the readjustment of the U.S. part of North American Geodetic Networks such validations are carried out in several steps (called project and block validation). However, also further checks of network completeness, connectedness and compatibility are carried out by adjusting several (Helmert)-blocks, see (Isner and Young, 1978).

2.3. Data integrity and security.

During the transformation of data from instrument readings or output to finally validated data it is important to assure the integrity of the data. This is not a problem, when one only deals with a small amount of data. But for big volumes of data we are faced with a serious problem.

Huge volumes of data are obtained using satellites or other space techniques like VLBI. This have made Ryan and Ma (1978) develop a data base handled for scientific applications, which main function is to keep track of data residing on magnetic tapes in a varity of formats and to create back-up files when necessary.

Data integrity may also be destroyed during numerical processing as pointed out in Poder and Madsen (1978). They describe a special type of variable (called a geotype variable) which will assure the integrity of angular data. With each variable is furthermore associated two data fields holding information about the units used and the number of significant digits, respectively.

The particular data security problems associated with the insertion of data in a data base are discussed in (Alger, 1978).

Finally it is worth noting, that the continuous use of the data for adjustment purposes results in the continuous validation of the data, and supports thereby the data integrity and security.

3. Geodetic data bases and data management

3.1. General considerations.

The concepts of a data base and a data base management system have been developed during the last ten years and are now finally fully clarified and agreed upon. A vast amount of literature has been published, see the last part of the literature list ([G1] - [G7]). A brief survey is given in Frank (1979).

When analyzing a data base one makes an important distinction between

(1) the internal level, (the physical data storage)

(2) the external level, (the data base viewed by one specific user and defined by an external schema)

(3) the conceptual level (the general view of the data base, defined by a conceptual schema)

The link between the different levels is the data base management system (DBMS), which handles all accesses to the data base.

The DBMS defines and performs the mappings between the different levels. Aided by the DBMS a user (called a data base administrator) must decide on (1) the content of the data base, (2) the storage structure and access strategy, (3) the external and conceptual schemas, (4) data validation and check procedures, (5) back-up and recovery and (6) the development of specific utility programs or routines. (For more details see e.g. (Date, 1977, Chapter 1)).

In the following subsections we will review which decisions different administrators of geodetic data bases have made or have planned to make. These decisions have naturally been influenced by the rationale behind establishing a data base, i.e. the planned use of the data base. The use of different data bases are summarized in Table 2.

3.2. Content of the data bases

A general discussion of the content of a geodetic data base can be found in (Tscherning, 1977). In Table 1 a survey is given of the content of different geodetic data bases. The table shows an interesting fact, namely that there exist three types of geodetic data bases:

I. The general data base supporting all types of geodetic operations (e.g. NGS)

II. The specialized, gravimetric data base serving as a national or global center (e.g. Bureau Gravimetrique)

III. The data base established at a geodetic observatory (IFAG, TU-Berlin)

The content of the data bases is in nearly all cases very well documented, see e.g. (Pfeifer, 1978). However, one feature which frequently is left out is the one described in (Poder and Madsen, 1978) and mentioned above. Such features, assuring data integrity, should be included in all old and new data bases.

A more detailed account of the data base content can be found in the referenced literature.

3.3. Access methods.

A general discussion of different access methods can be found in (Schwarz and Fury, 1977 and Tscherning, 1978, section 4).

Data bases which only have storage and retrieval functions tend to apply the simple sequential method of access. Otherwise index-sequential or direct access methods are used, cf. Table 2.

The index-sequential method requires the existence of unique identifiers. In cases, where these do not exist already, they must be constructed. Such constructions are not straightforward, and the problems encountered by NGS are very instructive: A first index was constructed using the station positions as given in NAD 1927 see (Alger, 1978). It was naturally simple to assign a number to trigonometric stations. Then other data types (e.g. astro-positions) had to be assigned the same number, however the matching had to be based on non-unique station names. This caused severe problems for which an interesting solution is described in (Fury, 1978).

Examples of unique identifiers for different data types are listed in Table 3.

3.4. External and conceptual schemas. Data models.

A discussion of different conceptual schemas or data models can be found in (Schwarz and Fury, 1977, Tscherning, 1978). These concepts are also discussed by (Kremers, 1979). External schemas does not seen to have been explicitly discussed in the geodetic literature.

Three data models are today generally used:

(1) The network model,
(2) the hierachical model and
(3) the relational model.

The model (3) can be regarded as a special case of (2), and model (2) as a special case of (1), see e.g. (Date, 1977).

The models differ mainly by implying to the DBMS different preferred way of accessing data. In the relational model it may be difficult to find out whether a specific instrument have been used in a specific station, while such information might be readily available in a suitably designed network model.

3.5. Data validation and check procedures.

Data validation during entry has been discussed in section 2.2. No further data validation and check procedures have been reported.

3.6. Back-up and recovery.

Back-up and recovery procedures are discussed in (Alger, 1978).

3.7. Supporting utility programs and routines.

The DBMS will perform the basic operations on the data like selection of data according to different criteria, see e.g. (Tscherning, 1978, Schwarz and Fury, 1977, Alger, 1978, Kremers, 1979). However it is frequently necessary to develop supporting utility programs and routines in order to achieve an optimal performance of the DBMS.

The most important supporting utility routines, which have been reported, are procedures for reference system transformation (Poder and Madsen, 1978) and gravity field interpolation or prediction (Poder and Madsen, 1978, Franke, 1979, Fila and Chamberlain, 1978).

Reference system transformation procedures permit that coordinates of points in different mapprojection coordinate systems can be readily computed. Coordinates resulting from different adjustments can not generally be transformed in a simple manner, but empirical interpolation-type techniques can be applied.

Instead of storing for each trigonometric and levelling station quantities like gravity, deflections of the vertical and geoid height, prediction procedures can be applied, if the horizontal and vertical position of the station is known. Such features reduce storage requirements, but may not necessarily be cost-effective as the prediction process can be very time-consuming.

4. Trends and prospects.

(Alger and Gurley, 1975) have investigated the possible use of commercially available DBMS. They concluded, that such systems were not feasible, because of the huge amount of data they had to deal with. NGS, therefore chose to develop its own system of which a detailed account is given in (Alger and Gurley, 1975, Schwarz, 1975, Schwarz and Fury, 1977 and Alger, 1978).

However, commercial systems have been used with success for smaller data bases as described by (McConnel, 1976, Madsen and Poder, 1978, Bayerische Landesvermessungsamt, 1978, Degerstedt and Schölin, 1979). (Some of the employed systems do not include all the facilities, which constitutes a DBMS).

The use of a central data base and the exchange of data between different data bases requires the standardization of data. The most important thing to agree upon is the content. Format standardizations are generally unnecessary, but may constitute reasonable guidelines.

Data standardizations are described in (Lepretre, 1976, Arbeitsgemeinschaft der Vermessungsvervaltungen, 1975, National Geophysic and Solar-Terrestrial Data Center, 1977, DMAAC, 1977, NASA, 1974 and most important: Pfeifer, 1978).

A future international exchange of geodetic data is necessary in order to create geodynamic information systems (see e.g. NASA, 1979). The further development of standards, which are agreed upon internationally, will therefore be an important task in the future. The International Association of Geodesy should play an active role in this process.

Another important trend is pointed out in (Riordan, 1978, Smith, 1979): Geodetic Data will become part of other data bases, which primary functions are the support of non-geodetic activities like land management or military weapon systems. (See Table 2). On the other hand, geodetic operations require the access to non-geodetic data bases containing e.g. digital topography or geological data (e.g. for terrain correction computation). The problems of the future development of geodetic data bases, therefore, have many non-scientific, but for the society important aspects.

Finally let us note that there still are many unsolved problems in the field of geodetic data handling:

Which access methods and which data models are most suitable ?

How can data-validation procedures be improved ?

What are the best ways of data entry ?

The solution to these problems should be possible during the next 4 years. However this presupposes that the established international cooperation in this field is continued.

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Table 1. Content of various geodetic data bases.

Agency	Horizontal		Vertical		Gravity		Astron. azimut		Station description	Other (code)*	Source Reference
	obs.	pos.	obs.	pos.	obs.	val.	obs.	pos.			
National Geodetic Survey, U.S.A.	x	x	x	x		x		x	x	6,8-12 18	1,2,22, 29,36,37, 39,41
Canadian Geodetic Survey		x		x					x	11	31
Danish Geodetic Institute	x	x	x	x	P	x		x	x	6,11, 16,17	30
Vermessungsvervaltungen, BRD		x		x					?		3
Bayerische Landesvermessungs Amt	x	x	x	x		P					4
Bundesamt für Eich und Vermessungswesen		x		x					?		16,48
National Land Survey Sweden		x		x		x			x	12	9
Maritime Provinces Canada	x	x	x	x		P		P	?	11,18	11
Defence Mapping Agency (HTC) U.S.A.		P		P				P	P	12,14, 17	Personal communic.
Org. f. Geodesy and Kart., Budapest		x							?		28
Inst. f. Angewandte Geodäsie, BRD.		x		x						2-6	46
National Ocean Survey, GRDL, U.S.A.										1	7
Tech. Universität Berlin										4,7	20
VEB Kombinat Geod. u. Kart., DDR.			x	x		x					13
Earth Physics Branch Canada					x	x			(Base Stations)	11,15	6,23
Defence Mapping Agency (AC), U.S.A.						x			"	1	10
Bureau Gravimetrique International						x			"	11,15	21
Nat. Geophys. S.T. Data Center, U.S.A.					x	x				11	27

* Codes used: Satellite altimetry = 1, Laser = 2, C-Band radar = 3, Meteorology = 4, Satellite orbit elements = 5, Doppler = 6, Earth-tide registrations = 7, Historical = 8, Cross-reference = 9, Geoid height = 10, Survey equipment = 11, Digitized topography = 12, VLBI = 13, Landsat = 14, Geological = 15, Photogrammetry = 16, Map-sheet reference = 17, Network connectivity information = 18.

P = planned, ? = not confirmed, by very likely.

Table 2. Access methods and function of various geodetic data bases.

Agency	Maintenance Storage Retrieval	Adjust-ment	Cadastral Landregi-stration	Mapping	Other	Access-method	Source Reference
National Geodetic Survey, U.S.A.	x	x				MI+S	1,2,22,29, 36,37,39,41
Canadian Geodetic Survey	x	x				IS	31
Danish Geodetic Institute	x	x		x		IS+S	30
Vermessungsvervalt-ungen, BRD	x		x			unknown	3
Bayerische Landes-vermessungs Amt	x	x	x			IS	4
Bundesamt f. Eich und Vermessungswesen	x	x	x	?		unknown	16,48
National Land Survey Sweden	x	P	x	x		IS	9
Maritime Provinces Canada	x	x	x	?		unknown	11
Defence Mapping Agency (HTC) U.S.A.	x			x	x	"	33
Org. f. Geodesy and Kart., Budapest	x	x				"	28
Inst. f. Angewandte Geodäsie, BRD	x	x				D+S	46
National Ocean Survey,GRDL, U.S.A.	x	x				D	7
Tech. Universität Berlin	x	x				IS+S	20
VEB Kombinat Geod. u. Kart., DDR	x	x				IS	13
Earth Physics Branch Canada	x	x				IS+S	6,23
Defence Mapping Agency,(AC),U.S.A.	x				x	S	10
Bureau Gravimetrique International	x					S	21
Nat.Geoph. S.T. Data Center, U.S.A.	x					unknown	27

? = not confirmed, but very likely, P = planned.

Access methods: Sequential = S, Index-sequential = IS
Multi-indexed = MI, Direct = D.

Table 3. Some currently applied indexing techniques.
(Methods for the assignment of unique station numbers or unique keys for observational data).

Agency	Station number derived from:	Key for observation or group of observations derived from:
National Geodetic Survey	a. Position b. State, Survey project, consecutive number	Station number, date/time observation type
Danish Geodetic Institute	Administrative area + concecutive number	Station number, field-book page, observation type
Institut f. Angewandte Geodäsie		Station number, Satellite number, time, observation type
NOS/GRDL, U.S.A.		Pass number, 5° Block number, geographical area boundary
National Land Survey, Sweden		
Canadian Geodetic Survey	Degree-square, project number, consecutive number	

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