MANAGEMENT OF A GEODETIC DATA BASE*

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Abstract: The basic operations to be performed on the data stored in a geodetic data base by a data base management system are described and exemplified.

Different types of data organizations are used or have been proposed such as index-sequential and multi-index file organizations for horizontal geodetic positions and observations. Preliminary recommendations concerning the use of the different data organization types are given based on a discussion of the impact of the data organization on the effectiveness of the data base management system.

1. Introduction

One of the main reasons for the establishment of the IAG SSG 4.38 Working Group "Application of Computers for the Handling of Geodetic Data" was the upcoming readjustment of the North American Geodetic Networks. It was obvious that this readjustment, besides new requirements for observational data and improved numerical techniques, posed a very difficult problem of efficient and fast data handling.

Existing commercial data base management systems had been analyzed by U.S. National Geodetic Survey (NGS), but no one seemed to fulfill the requirements (Alger and Gurley 1975: 3). So, a whole new design of a data base and a data base management system was initiated (Schwarz 1975, Schwarz and Fury 1977).

In a first working group report (Tscherning 1977), the content of a geodetic data base was discussed. Following Lindgreen (1974), the content was viewed as data representing sets of information elements, i.e., triples consisting of an entity, a property, and a value. In this report we will discuss different types of data organizations which are used or have been proposed for geodetic data. However, we will first define more abstractly operations on information sets in order to clarify the operations which a *data base management system* must be able to carry out. The effectiveness and speed of these operations will depend on the chosen data organization. Based on a discussion of this dependency, preliminary recommendations concerning the use of different types of data organizations are given.

* Interim report of International Association of Geodesy, Special Study Group 4.38, Working Group, "Applications of Computers for the Handling of Geodetic Data."

TABLE 1.—*Example of a homogeneous information set.*

	Station number	φ	λ	Source code	Datum
	624	56° 34′ 12″.43	12° 44′ 12″.03	1970 110–21	ED50
Isonymous set	615	56° 01′ 15″.10	10° 00′ 32″.58	19700110–21	ED50
	302 A	55° 32′ 20″	9° 34′ 41″	19250730–00	ED50
	302 B	55° 32′ 21″.08	9° 34′ 41″.03	19700110–21	ED50
			Isotypic set		

2. Basic Operations on Information Sets

Recall that a set of information elements related to the same entity form an *isonymous* (information) set. Sets with the same property component are called *isotypic* (information) sets. A homogeneous information set consists of isonymous sets with the same property component or equivalently of isotypic sets referring to the same sets of entities. This corresponds to viewing data given in a tabular form either as a collection of rows or a collection of columns, cf. table 1.

Sets of information elements may be dealt with in the same manner as done in elementary mathematical set theory. We may, for example, count the elements, form unions, intersections, or differences.

Seven basic operations may be defined on homogeneous information sets. (The set of all information elements is also such a set.) These operations are independent and can be used for constructing more complex operations. The operations are:

Inclusion, operates on two sets with different entities, but with the same properties. The result is a new set with the same properties, and entities equal to the union of the two original entity sets. Example: two new sets of coordinates are added to table 1.

Extraction, operates on one set and isolates one or more isonymous sets. The result is a new set with the same properties, but with only a subset of the original entities. Example: the two last rows are extracted from the table.

Conglomeration, operates on two sets with different properties, but with the same entities. The result is a new set with the same entities, but with properties equal to the union of the two original property sets. Example: two new columns containing the standard deviations of the coordinates are added.

Separation, operates on one set and isolates one or more isotypic sets. The result is an isotypic set with same entities, but having only a subset of the original properties. Example: the list of station numbers is separated.

Derivation, operates on the values of one or more properties. The result is an isotypic set of elements for which the entities have values fulfilling some specified condition(s). Example: a list of station numbers for stations with latitude > 56°.

Detection, operates on the values of one or more properties. The result is the set of entities for which the values fulfill some specified condition(s). Example: a list of the numbers of the rows in the table which contain stations with latitude > 56°.

Exposition, operates on an isotypic set, and the result is the set of *values* from all the single elements. Example: the two source codes occurring in table 1.

The process of *selection*, which is basic to all information retrieval systems may be defined as consisting first of all of a *detection* of the set of entities which fulfill certain conditions, followed by an *extraction* of the corresponding isonymous sets, on which finally a *separation* takes place.

From the above very simple examples, it is obvious that any data base management system for a geodetic data base must be able to carry out these operations. However, the ability to carry out these operations and the speed of the operations will depend on the data organization used. We must also note that a geodetic data base generally will contain not only one, but many homogeneous information sets. On the other hand, it is also clear that the fewer different sets, the better.

3. Applications of the Geodetic Data Base

In any application of computers, the purpose of the effort must be spelled out in detail. Only then can one identify and judge the relevance of the data elements contained in the files, the processes required to manipulate the data, and the file structures which will enable the processes to be effective (Wiederhold 1977: 23). In section 2 we saw that the basic data management processes were relevant for geodetic data: however, to evaluate different file structures, we must be more explicit. Currently, the main purpose seems to be the use of the data base for data storage and retrieval (Buck and Tanner 1972; Chin 1977; Dotson and Reinholtz 1975; McConnel 1977; Spencer 1977).

Some typical applications are the following: (1) Select preliminary geodetic coordinates for an adjustment, given list of station numbers. (2) Select *all* observations which will be used in an adjustment of a geodetic network (horizontal, vertical, gravity, altimeter). (3) Select datum parameters to be used in an adjustment or gravity field approximation. (4) Create list of station numbers based on a description of area and kind (order) of stations participating in an adjustment. (5) Select gravity observations spaced as uniformly as possible within a given area. (6) Extract description and coordinates for a trigonometric station. (7) Add 10′ to scale reading, second round, from stations 621 to 630, carried out 1963.01.10 at 10:30 a.m. (8) Include (a new) station 701 in the station file, with its preliminary coordinates. (9) Find all observations where instrument No. 381 has been used in a specified time period.

We will less often see applications like (9) but this application may very well be useful when analyzing the performance of instruments (or observers).

It is obvious that not all these applications need to be carried out with the same speed. It should naturally be possible to obtain information about a single station very fast, whereas selections like (5), above, generally do not need to be executed very fast. On the other hand, if a big file will have to be searched first, before the data within the given area are found, then the whole process may put a heavy load on the computer supporting the data base.

This problem is very typical for the most frequent applications, and the solution is simply to organize data according to some geographical division of an area (5° by 5° equal area blocks (Chin 1977)), quadrants and 8° latitude bands (Dotson and Reinholtz (1975)), 30′ to 7½′ blocks (QID) (Alger and Gurley 1975). (By creating this geographical division, a new set of entities has been constructed. The properties of these entities will be their boundaries and e.g., the identification numbers of the trigonometric stations within the area.)

4. Data Organizations Suitable for Geodetic Data

In the following we will assume that the reader is familiar with basic terms like file, record, and index. Typically geodetic data will be stored in different files containing, e.g., horizontal positions, "horizontal" observations, vertical positions, "vertical" observations, astronomical positions, and gravity values. Several of these files contain related data elements, e.g., quantities all related to the same station. One method of representing these interrelations may naturally be to have only one file, where each record then contains all information about one entity, e.g., a trigonometric station. This seems to have been the idea behind the NGS data base design (Schwarz 1975), where horizontal positions, observations, and station descriptions are collected in one file. At the Danish Geodetic Institute these data are kept in three separate files.

The advantage of keeping related data together is naturally that updates and selection processes are more easily executed. The update of the positions related to a gravity station is today nearly impossible because the geodetic position files and the gravity files are not related through station identification numbers in most geodetic data bases. On the other hand, several applications will only require access to the horizontal positions, but the station descriptions are irrelevant. For such applications, the "smallest" files seem to be the most suitable. It will then be the task of the data base management system (using the *conglomeration* operation) to establish a file with a bigger set of values when such a file is needed.

Let us now regard the single files. These files will be used to store, update, and retrieve data. Of importance here is then how much storage space the file will occupy, how easy the updates can be executed, and how fast data can be retrieved. This will all depend on the selected file organization. Generally, six basic file methods are used, the pile file, the sequential file, the index-sequential, the multi-indexed file, the direct file, and the multiring file (Wiederhold 1977: 160). The performance of these file methods may be evaluated having as parameters the degree of "structure" found in the data, the possible variation in record size, and the type of retrieval which is needed (fact-finding, subset-summary, or exhaustive-summary) (Wiederhold 1977: 161).

Geodetic data will generally be well structured. The record size will vary, and both factfinding and subset-summaries are important. For well-structured data, the sequential organization will require the least storage space. The index-sequential, the direct, and the multiring methods will require some extra space. If it is important to save storage space, these methods must be preferred. Considering the huge volume of data dealt with in data bases holding gravity or satellite altimetry data, we also see that the sequential method has been preferred (Chin 1977; Dotson and Reinholtz 1975; McConnel 1977).

As mentioned above, fast updates do not seem to be an important aspect of geodetic data handling (as compared to for example an airline seat reservation system). However, if this had been the case the pile and the multi-indexed method would have been the best choice.

Fact finding (cf. section 3, application (6)) and retrieval of subset summaries (cf. section 3, application (1), (2), (4), (5)) must be considered to be the most important applications. For data selection in connection with an adjustment of a geodetic network or geoid or deflection of the vertical computation, the subset summary retrieval is the most important. For fact finding the multi-index method is excellent, but the indexed-sequential, the direct, and the multiring methods are also good. For subset summaries the multiring method is regarded as excellent, while the multi-indexed method is regarded as good.

The multi-indexed method is the one proposed and used by NGS (Schwarz 1977), and it seems to be an excellent method for handling geodetic data. At the Danish Geodetic Institute the index-sequential method is basically used. However, the single records in the files which are used for fast data retrieval (the horizontal position file) contain pointers to the single data-elements, so that the file in reality is structured as a indexed file.

Let us again regard the whole data base, which will consist of several different files. The values of properties of one entity may hence be found in different files. In order to describe this situation a model for the whole data base must be established. For this purpose several models can be used: the relational model, the entity model, the hierachical model and the network model (Wiederhold 1977: 366). The entity *model* makes it possible to use different definitions of an entity (i.e., instead of regarding the trigonometric stations in table 1 as entities, the "source" may be regarded as an entity). In the *network* model also all cross-references between trigonometric stations between which observations have been carried out will be explicitly represented.

The *hierachical* model has been discussed by Schwarz and Fury (1977). Here the data are viewed as having a tree-structure with roots being the station identification number and leaves being the single-scale readings (the observations). This model corresponds very well to the multi-indexed file mode. The drawback is that some of the basic data management operations (cf. section 2), namely conglomeration and separation, are not easily defined and rarely are implemented (Wiederhold 1977: 426). This is a severe inflexibility which must be taken into account when implementing a data base. In practice it means that it is very difficult to add a new property to the property set (as for example the day and time of the observations, if this was not included in the original file).

The *relational* model, however, does not have this drawback. This model can be established when the values of one isotypic set can be used as identifiers (such as the station number in table 1). The basic *binary relations* are then formed by the entity identifiers and the property value—or more correctly by the two properties and the two values. The data representation of n isonymous information elements is called a *list* or *n-tuple*. A homogeneous information set is called a *relation*. The identifiers are called the *ruling part* and the other values the *dependent part* of the relation.

In the same manner as for homogeneous information sets, set theoretical operations can be defined for relations and are contained in programming languages like APL. Note that the file organizations which correspond most directly to this model are the sequential and the index-sequential models.

5. Conclusion

The evaluation of different file and data base models and of data base management systems for a geodetic data base is not possible without having experience with actual implementation. Unfortunately not much literature has yet been published about the functioning of data bases containing, e.g., horizontal and vertical position or observation data. However, simple data base systems for gravity data are known to function excellently using mostly the sequential file method. These data bases mostly are used only for data storage and retrieval.

From more theoretical considerations, it can be concluded that the multi-indexed file method should be excellently suited for geodetic data. However, the related hierachical data model seems to contain an inflexibility which makes it less suited for geodetic data.

Thus, the users and designers of geodetic data bases are encouraged to make investigations in this field, so that more precise recommendations about advisable file methods and data base models can be used.

In this report we have mainly regarded the data management system as supporting data retrieval functions. However, the experiences at NGS (Whalen and Balazs 1976) show that many applications can be found in the field of storage and analysis of observational data. Further investigations and experiments in this field are therefore strongly recommended.

Literature

(A) Management of Geodetic Data

Alger, D. E. and Gurley, J. C., 1975. A design for a geodetic data base management system. *Proceedings of the American Society of Photogrammetry*, 41st Annual Meeting, Washington, D.C., U.S.A., 1975.

Buck, R. F. and Tanner, J. G., 1972. Storage and retrieval of gravity data. *Bulletin Geodesique*, 103:63–84.

Chin, M. M., 1977. *GRDL Altimeter Date Base Users Manual*. Business and Technological Systems, Inc., BTS–TR–77–40.

Dotson, L. L. and Reinholtz, E. B., 1975. Holdings, storage and retrieval of DOD gravity library data. *DMAAC/RP–75–003*, Defense Mapping Agency Aerospace Center, St. Louis AFS, Mo., U.S.A.

McConnel, R. K., 1977. The National Gravity Data Base. Preprint, Earth Physics Branch, Ottawa, Canada.

Porter, T. A., 1974. Canadian National Positional Control Survey Data File, A Geodetic Data Bank for Canada. *The Canadian Surveyor*, 28(5):724–731.

Schwarz, C. R., 1975. The Geodetic Data Base at NGS. Presented at the XVI General Assembly of IUGG, Grenoble.

Schwarz, C. R. and Fury, R. J., 1977. The geodetic data management system at the National Geodetic Survey. Presented to the International Symposium on Optimization of Design and Computation of Control Networks, Sopron, Hungary.

Spencer, John F., Jr., 1977. The National Geodetic Data Center: today and tomorrow. *Proceedings of the American Congress on Surveying and Mapping*, Little Rock, Ark.

Stem, James E., 1976. The NGS data base as a central depository of geodetic control data. *Proceedings of the American Congress of Surveying and Mapping*, pp. 49–57.

Tscherning, C. C., 1977. Defining the basic entities in a geodetic data base. Presented at the International Symposium on Optimization of Design and Computation of Control Networks, Sopron, Hungary (also in print, *Bulletin Geodesique*).

Whalen, C. T. and Balazs, E., 1976. Test Results of First-Order Class III Leveling. *NOAA Technical Report*, NOS 68 NGS 4.

(B) Selected General Literature on Data Bases

Auerbach, 1975. *Auerbach Guide to Data Base Management*, Auerbach Publishers, Pennsauken, N.J.
Date, C. F., 1975. *An Introduction to Database Systems*, Addison-Wesley.
Fry, James P., 1976. Evolution of data base management systems. *Computing Surveys*, 8 (1):34–42.
Lindgreen, Paul, 1974. Basic Opreations on Information as a Basis for Data Base Design, *Information Processing* 74, North-Holland Publishing Company, pp. 993–997.
Wiederhold, Gio, 1977. *Database Design*. McGraw-Hill, Inc.

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Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks

held at

The Marriott Hotel
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April 24 to 28, 1978

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