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OPTIMIZATION IN RESOURCE MAPPING
IN WESTERN CANADA

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ABSTRACT

The inventory of natural resources involves mapping applications which are challenging to photogrammetric and other engineers. The position-based data constitute overlay information for base maps of appropriate scales, accuracies and representations.

The transition phase from the traditional analog and graphical methods to modern analytical and digital techniques is particularly critical for any organization. The methodology of systems engineering and operations research can be used for the modeling and optimization of such situations with the application context characterized by system variables.

Practical examples of resource mapping in Western Canada are described and various solutions are analyzed. Applications in other contexts are also briefly discussed.

0. - Introduction

The inventory and management of natural resources require a mapping programme to provide the authorities with upto-date comprehensive information. For planning purposes and policy decisions, relatively small-scale maps may be sufficient but for efficiency in the execution of the tasks, the resource mapping programme must be carefully planned, coordinated and implemented with appropriate revision cycles.

Such resource information maps can be very different depending on the specific objectives under consideration. Photomaps, or even photomosaics, can provide all the necessary background information in some contexts. However, conventional line maps are usually more appropriate as base maps for overlaying the information about the natural resources. With the current trends towards automation in mapping, digital maps are becoming more important in view of topographical data banks and computerized drafting operations [e.g., Zarzycki, 1978].

The sequence of operations required in the preparation of a resource map can be expressed in terms of the following:

- . preparation of an appropriate base map,
- . collection of the resource information,
- . generation of overlays for the base map,
- . completion of the cartographic documents.

These operations are greatly dependent on the nature of the resource information, the scale, accuracy and cartographic specifications for the resource mapping under consideration.

The optimization of such resource mapping operations has become necessary to ensure the efficiency and reliability of the resource maps. Over the past few years, the situation has evolved especially in the direction of increasing importance for the economics of the mapping operations and the accuracy of the resource inventory information.

One critical aspect of resource mapping in North America is that numerous base maps will require revision within the next five to ten years. The redefinitions and readjustments of both horizontal and vertical networks, planned for about 1983 and 1987 respectively, will imply relatively large coordinate changes in the positions of geodetic control stations [e.g., Beattie et al., 1978; McLellan, 1978; McLellan et al., 1978; Lachapelle, 1979].

Among the various approaches to optimization in resource mapping, the engineering systems methodology is considered in the following analysis. This approach is used first, for the position-based resource information system and second, for the resource mapping operations system. The methodology essentially consists in modelling the systems in terms of some appropriate parameters such that the optimization problems can be formulated in terms of all the available information. Some practical examples will be included in the following discussion, whenever possible.

1. - Base Mapping

The base map is the document onto which the resource information is to be transferred from photographs, remote sensing records or some other sources. Thus the base map must satisfy the scale and accuracy requirements for the

resource mapping project and include the topographical details necessary on the resource map. However, a base map is not a complete topographical map and depending on the resource information context, the optimum scale, accuracy and representation have to be worked out.

The simplest solution to the preparation of a base map consists in enlarging or reducing existing topographical maps with appropriate modifications of topographical details for the resource mapping. Various complications can easily arise with this approach when the mapping scales are too different, especially with accidented topography. An example of this solution is in the Fundy Forestry Project where a set of 10 base map sheets at the scale of 1:12 500 was prepared by enlarging 1:50 000 map sheets of the National Topographical Series with the addition of a 1 km square grid for forest resource mapping purposes [Madill and Aldred, 1977].

Photomaps and orthophotomaps are also used extensively in some contexts as work documents in resource inventory projects. A base map with a photographic background is often not acceptable unless that background is toned down significantly. Furthermore, identification and transfer problems are more common with a photo or orthophoto base map.

In the preparation of a conventional line base map, the usual procedures employed in topographical mapping can of course be used. Unfortunately, in the Western Canadian context for instance, the terrestrial control information is often very sparse for block adjustments corresponding to map scales between 1:20 000 and 1:10 000. In some cases, however, control points can be transferred from the aerial triangulation diapositives used in the small-scale topographical mapping of the same area.

It should also be noted that for the purposes of resource mapping, the accuracy requirements are usually less demanding than for topographical mapping at the same scale. There is however every reason to attempt achieving the best accuracy in base mapping for the terrestrial control information available. A good base map can serve the purposes for different resource inventories, drainage patterns, geological and geophysical applications, and so on. Furthermore with the North American geodetic network readjustments a few years away, it appears greatly advantageous to be able to revise rigorously adjusted photogrammetric blocks in a most efficient manner.

The SPACE-M photogrammetric block adjustment approach is most appropriate to handle very large blocks of stereomodels with very sparse terrestrial control [Blais, 1977 and 1979a]. The use of auxiliary control information, such as lake surfaces as levelling constraints, is an important consideration in the Canadian context. The revision of previously adjusted photogrammetric blocks when the new coordinates become available for the control points can then be carried out most efficiently. Those new coordinates for the control points may come directly from the readjustment of geodetic networks, or indirectly through an estimation procedure such as with the program ESTPM (i.e., Estimation of Secondary Terrestrial Positions for Mapping) [Blais, 1979b].

2. - Resource Inventory Information

The resource information which is to appear on the base map can be very different in different contexts. For instance, it may consist of only

numerical quantities which are to be differentiated using some symbolization scheme. It may also consist of areal information which can be represented graphically or numerically on the base map. Finally, it may consist of spatial information which is to be exhibited using contours (possibly with shading) or otherwise on the base map.

For the base map to serve equally for the different types of resource information, it is necessary that this base map be a spatial one. A planimetric base map may be sufficient in some contexts but for the majority of resource mapping purposes, the height information is also required. This height information need not be shown on resource maps where it is not relevant but should nevertheless be available as an overlay whenever required.

The representation mode or format for displaying the resource information on the base map would greatly depend on the nature of the information. The most important considerations are to the effect that the information contents be optimized in their graphical and/or numerical modes of representation for the intended users.

In the same context, the natural correlations between the different types of resource information should be preserved whenever possible. For instance, forest resources are intrinsically correlated with soil types and drainage patterns. The implication is that without proper coordination, valuable information is lost in the process of resource mapping.

The digital approach to resource mapping offers far greater flexibility in planning and carrying out the resource mapping operations. Data bases and banks can be designed to accommodate the different groups involved in resource mapping so as to optimize the mapping operations and facilitate the maintenance of the data files. The various user requirements can thus be satisfied more efficiently.

3. - Systems Aspects and Optimization

Resource inventory data constitute a position-based information system with well-defined functional characteristics and objectives. Such an information system can be studied for self-consistency, accuracy and optimum representations for the potential users. In addition, the information content of such a system is time-dependent and therefore requires maintenance to fulfill the intended objectives.

Resource mapping operations also constitute an engineering system of inter-related operations which lend themselves to modelling and optimization. The system modelling generally assumes some appropriate network configuration for the different processes involved. The system parameters have to be carefully chosen for the modelling in order to ensure meaningful optimizations.

A number of optimization problems have already been indicated concerning the resource information systems and the resource mapping operation systems. The modelling of those systems usually involves both deterministic and probabilistic parameters depending on the applications contexts. The models themselves can be linear or nonlinear and may include constraints of various types [e.g., Wagner, 1975; De Man, 1979].

The base mapping operations can be optimized for accuracy, efficiency and appropriateness for the resource inventory information. With the general trend towards digitization and automation, an additional dimension is being added to the base mapping and the overlaying of resource information. For instance, the scale of mapping with digital information can be varied at will within the range of resolutions of the data.

Concerning the preparation of resource information overlays, the information content and accuracy are the natural objects for optimization. Depending upon the user requirements and preferences, other aspects of resource mapping such as the appropriate formatting of the data through generalization or specialization may also become very important.

The updating aspects of resource mapping also require serious considerations. The resource inventory information is by nature time-dependent and map revisions cannot really be avoided for too long a period. In most applications, this simply means a revision of some of the map overlays. However, in other contexts, the base map itself requires revision such as in the case of a major readjustment of the geodetic networks. With proper planning, the revision of the base maps together with their overlays can be carried out in a straightforward manner.

4. - Applications in Western Canada

A wide spectrum of topographical and climatic conditions characterize Western Canada, which includes the four western provinces and the southern parts of the Yukon and North-West Territories. The coastal areas near the Pacific Ocean are often excluded from considerations in the present context.

The topography varies greatly from the flat prairies to the well-known Rocky and Coastal Mountains. The northern areas have harsh climate conditions with short growing seasons while the southern areas are semi-arid in places. Annual precipitation averages only 30 to 40 cm in most of Western Canada. Such factors have significant implications for inventory mapping of the same resource in different areas as well as different resources in the same area.

In the context of forest resource inventory, both wide-angle and narrow-angle photography is used in British Columbia. In order to reduce timber cruising on the ground, very-large-scale small-format sampling techniques are used in British Columbia, Alberta and the Yukon. An open question concerns the possible applications of such techniques in other areas of Western Canada as well as other resource inventories.

In numerous contexts, the mapping operations are only optimized in terms of specific requirements. For instance, the following situations deserve serious considerations from the optimization point of view:

- (a) Slotted template methods of control extension in forest resource mapping.
- (b) Accurate aerial triangulation for 1:50 000 topographical mapping with photography which is more than 10 years old in places.

- (c) Aerial photography at the scale of 1:12 500 for photointerpretation purposes only.
- (d) Super-wide-angle false colour aerial photography at 1:100 000 for agriculture purposes only.
- (e) LANDSAT photography with reflexive spectral signatures for monitoring and updating applications.

Concerning the map updating operations, some criteria for their optimization are given in [Thompson, 1979]. Another aspect of resource inventories is the type and importance of user activities. The lower limit for large-scale map users can be set by the route location analysis [e.g., Blaschke, 1972; Aird, 1975], while the upper limit for small-scale users can be set as in the Canada Land Inventory programme [McCormack, 1972]. However, with the increased flexibility associated with digital data, the concept of map scale has lost much of its importance.

5. - Concluding Remarks

Resource mapping involves two types of systems: a position-related information system and an engineering system of mapping operations. The information system can be optimized in terms of the information contents and the user requirements. The mapping operation system can be optimized in terms of efficiency and economy of the operations as well as in terms of the accuracy and quality of the resource maps.

Any optimization in resource mapping is also constrained by the available technology. This aspect of applied optimization is most critical when considering solutions to be implemented in an existing production system. With the recent advances in space, inertial and computer technology, the situation can change very quickly for the different resource mapping operations [e.g., Thompson, 1979].

On the other hand, any major technical advances in resource information systems will likely require a much wider familiarity with the mathematical concepts involved [White, 1978]. For instance, notions of topology, graph theory and lattice theory may very well be necessary for any further optimization of resource information systems.

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