AGGREGATION HIERARCHIES FOR MULTIPLE SCALE REPRESENTATIONS OF HYDROGRAPHIC NETWORKS IN GIS.

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ABSTRACT

An important aspect of the representation of terrain objects in GIS is the level of geometric and thematic detail, which is related to the scale of the terrain description. Different sets of elementary objects may exist at different scale or aggregation levels within the same thematic users context. These levels may be related by the fact that elementary objects at one level can be aggregates of elementary objects from a more detailed level, so that *aggregation hierarchy structures can be defined. A conceptual model for automated* generalization of hydrographic information is presented. Topological relationships are fundamental in the definition of the aggregation rules to compose complex hydrographic objects from elementary objects. The Formal Data Structure for single vector structured maps as proposed by Molenaar [2] is used to model terrain data in a GIS environment. An application has been developed to obtain multiple scale representations using the combination Arc/Info and Oracle RDBMS.

1.- Introduction.

This paper presents the definition of an aggregation hierarchy for multiple representations of hydrographic data within the context of conceptual generalization (information abstraction) process. This process will make use of a database representation of a drainage network with its catchment areas based on the formal data structure (FDS) for single valued *vector maps [2]. This FDS combines aspects of object-oriented and topologic data models.* Point, line and area objects are represented with their geometric and thematic aspects. Their geometric representation supports the analysis of topologic object relationships, whereas their thematic description is structured in object classes that form a generalization hierarchy. This class hierarchy in relation to the topologic object relationships supports the definition of aggregation hierarchies of objects. The classification and aggregation hierarchies play an important role in the definition of spatial objects, since they are related to the detail of information that can be represented at a given mapping scale. Accordingly, these structures are fundamental in the definition of rules for modelling generalization of spatial information at different resolution levels [4].

Topological object relationships can be used to establish the connectivity of a drainage network and the adjacency of the drainage elements and catchment areas. These relationships in relation to water flow data are fundamental in the definition of the aggregation rules to compose complex hydrographic objects from elementary objects. The capacity of Geographical Information Systems (GIS) to register and handle topological information makes them very useful tools for the automation of conceptual generalization of spatial data.

2.- The hydrographic data model.

At a given scale, the basic hydrograpic information consists of the drainage network, composed of a set of connected channels or drainage elements, and their catchment areas. The drainage elements can be represented either as eroded areas or as water course lines (depending on the application, Figure 1).

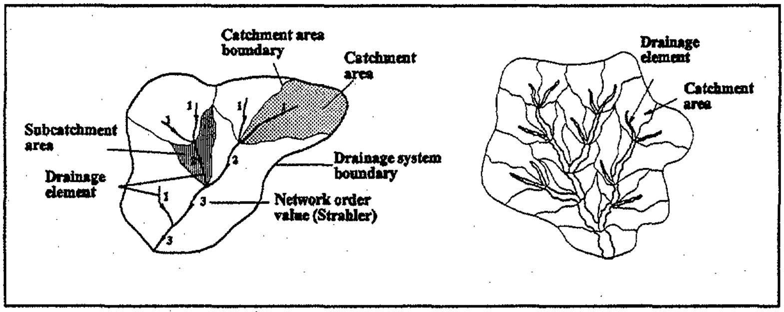

Figure 1.- Representation of basic terrain characteristics according to the proposed hydrographic data model.

The catchment of each element is the upstream area flowing to its outlet as overland flow, (channel flow from upstream catchments is not included). It is simply part of a hierarchy, in which a given catchment is a part of a larger one. Each catchment is assigned to a class, i.e. an erosion class [1].

3.- The conceptual model for generalization.

In a cartographic context, generalization can be defined as the process of abstracting the representation of geographic information when the scale of a map is changed. It is a complex process involving abstraction of thematic as well as geometric data of objects. The process usually involves two phases: a) a **conceptual generalization phase**, which implies the determination of the content of a representation in the generalized situation (information abstraction), and the definition of rules how the generalized objects can be derived from the objects at lower generalization level, b) a **graphical generalization phase** (cartographic generalization), which implies the application of algorithms for geometric simplification of shapes and for symbolization to assure map legibility.

Information abstraction in these subprocesses is mainly determined by expert knowledge and can be usually expressed as logical rules. These rules are susceptible to be traslated as database management procedures in a GIS environment [1,5]. Regarding information abstraction, several processes are recognized [4]: classification, association, generalization (class) and aggregation. Among all of them, class generalization and aggregation are directly related to changes in the level of definiton of objects when the mapping scale changes. Aggregation is based on the combination of elementary objects to build composite objects. The complexity of the objects will increase with the aggregation level since they inherit the thematics from their constituents. An aggregation process will be based on two types of rules [3]: a) rules specifying the classes of elementery objects building a composite object and b) rules specifying the geometric characteristics (i.e. minimum size) and topological relationships that these elementary objects have to accomplish (i.e. adjacency, connectivity, proximity, etc.).

These rules can be represented in a structure called aggregation hierarchy [3,5]. This type of information structure was selected to support the automated conceptual generalization of hydrographic data in the present research.

The definiton of the aggregation hierarchy for hydrographic information is based on interpretation of hydrographic features by experts at different scales. At a given scale, a specific set of drainage elements can be recognized and mapped according to their size, network order (i.e. Strahler) or a combination of both. Also, their catchments can be delineated (see paragraph 2). At a lower resolution scale, for the same terrain situation, less drainage elements could be mapped since some of them would not be representable because of their smaller size than the new critical size or their low order. Therefore, their catchments would not be delineated as individual objects either but merged to the catchments of the elements that the no representable connect to. Figure 2 shows a graphical representation of the defined structure [1].

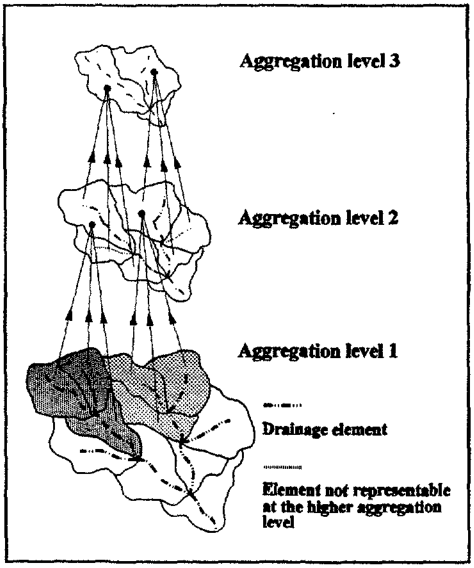

Figure 2.- Aggregation hierarchy structure of basic hydrographic units.

In each application the user's context will determine the range of alternatives for selecting and representing drainage elements to appear on a representation.

The transitions from a lower aggregation level to a higher level can be formalized as a set of information abstraction operations for [1]:

- **Selection** of drainage elements making up the data model at the higher level and the catchments to be aggregated. This operation is based on elements size, target scale, hierarchical order in the network and topological relationships among drainage elements (connectivity and water flow).
- **Elimination** of not representable drainage elements at the target scale.
- **Aggregation.** Determination of catchments to be merged (based on adjacency of areas and conectivity of not representable elements), and merging of catchments.
- **Reclassification** of hierarchical order of the remaining drainage network and thematic aggregation of resulting catchments (i.e. erosion class).

4.- Implementation and results.

As proposed by Richardson [5], the automation of information abstraction processes can be undertaken from a database perspective, by exploring the possibilities of the underlaying spatial data structures (in particular classification and aggregation hierarchies), and geo-database management system capabilities.

The proposed conceptual approach for hydrographic information abstraction requires manipulation of topological relationships at terrain object level (network connectivity, water flow and catchments adjacency). In this case, a vector topological-structured data model environment (ArcInfo) is used. Here, topology is stored at geometric element level (i.e. node, arc), but the database should be structured so that topological relationships between terrain objects and geometric elements can be recorded. Then, answers to queries on topological relationships between terrain objects can be easily handled [6]. Therefore, one of the core aspects on automation of conceptual generalization processes in a GeoInformation System environment is the definition of the conceptual database model. In the present research, the definition of this model is based on the Formal Data Strucutre (FDS) for single valued vector maps [2]. This model structures thematic data of spatial objects in hierarchically ordered classes and the geometric data in a topological model. The topologic relationships among data model components are recorded at three levels: geometric primitives (arcs and nodes), geometric primitives - objects and between objects (Figure 3).

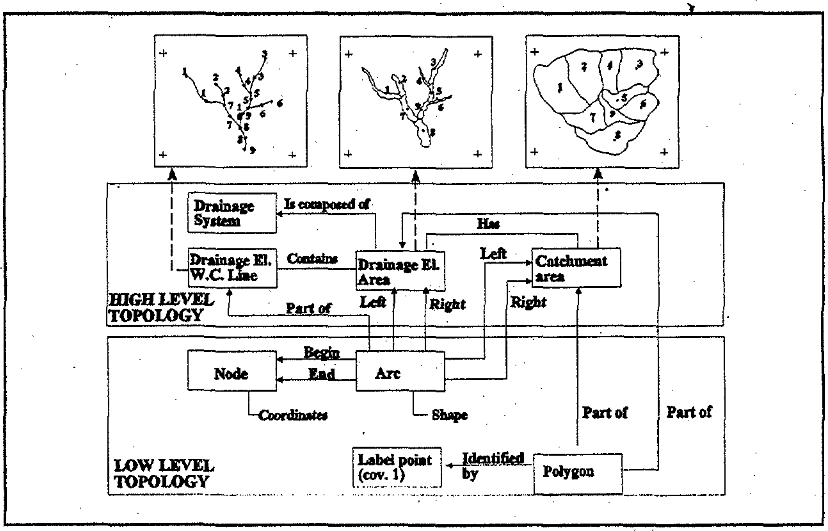

Figure 3.- Conceptual model of the hydrographic database based on the implementation of the FDS [2] in ArcInfo [4]. In the upper part: graphical representation of the basic spatial objects considered in the model as implemented in ArcInfo.

The automation of the aggregation process is based on a recursive strategy [1]. This has been implemented as procedural operations in a RDBMS environment (combination of ArcInfo and Oracle). First, the outermost drainage elements (Strahler order = 1) are checked to match the size requirements according to the target scale and cartographic rules established by the user. The elements that are not representable are selected and eliminated, their to-node or outlet point are used as dissolve items to merge the catchments. The remaining network is reclassified and a new selection starts. The process stops when no first order elements are selected according to the user's criteria. The methodology implemented in the prototype system has been applied to a data model containing the relevant hydrographic data of a catchment of the Alt Penedès region (NE Spain), mapped at scale 1:50.000. The width of drainage elements was used as criteria to determine their representation. A critical width of 0.5 mm (map units) was established. Figure 4a shows the graphical representation of the original hydrographic database while Figure 4b shows the representation after the automated generalisation at scale 1:100.000. Here, all the elements having an average width less than 50 m were eliminated and their catchments aggregated according to the proposed method.

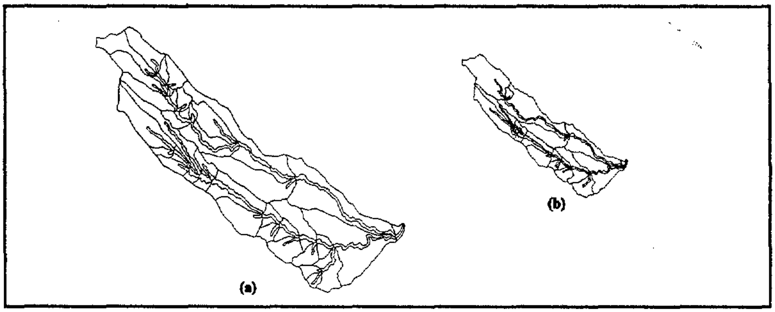

Figure 4.- Example of the application of the proposed method for conceptual generalization of hydrographic information: (a) original situation (original scale 1:50.000) and (b) after information abstraction (original scale 1:100.000).

5.- Conclusions.

A conceptual model for automated generalization (information abstraction) of hydrographic data has been presented. The model is built upon the basis of an aggregation hierarchy structure. Topological relationships have been shown as fundamental in the definition of the aggregation rules. The implementation of this model in a GIS environment (considering a database perspective) has been dene using the underlaying data structure provided by the Formal Data Structure (FDS) for single vector structured maps as proposed by Molenaar [2]. The FDS provides the required topoligical relationships to establish the aggregation hierarchy of the catchments on which conceptual generalization of hydrographic data is based.

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