GENERALISATION FROM LARGE TO MEDIUM AND SMALL SCALE ORDNANCE SURVEY MAPS USING EXPERT SYSTEMS TECHNIQUES

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ABSTRACT

Definitive procedures have been developed which are effective to varying degrees in specific areas of generalisation. In many cases, however, the variables involved such as change in style, are difficult to quantify and to manipulate with precise rules or 'hard' logic. The approach proposed here is one in which the 'hard' logic of established methods are combined by the 'fuzzy' logic techniques used in expert systems

<u>Introduction.</u>The Ordnance Survey (O.S.) has evolved a set of unique styles throughout its range of topographic maps which both define and characterise the British landscape. In this the O.S. are considered by many to lead the world. Automating these stylistic nuances is, however a very different matter. The large scale 1:1250 map series is the obvious starting point for the generation of digital data and the 1:625000 route map has led to an accomplished end product coupling a full digital database with an output module capable of producing a map of publishable quality. The medium scales however have remained elusive and although the 1:50000 series in particular is desirable in digital form it appears to be uneconomic as an independent commercial product. There is a clear need for a bridge from the existing digital data, now burgeoning, to this scale and thence to smaller scales which are stylistically and structurally related. This paper outlines an approach to this problem which is intended to accommodate the impressions involved with the stylistic change while maintaining inherent topographic accuracy. The following sections briefly describe the techniques that have been developed for automated generalisation and outline generalisation to date in a computer-oriented or "information Science" way and finally describe recent research.

GENERALISATION

<u>Manual approach.</u> The professional cartographers approach is typically full of a mixture of aesthetic design assessments combined with clear analysis of the requirements and data, a characteristic of the Cartographers art which makes computer cartography so demanding.

Figure 1b depicts a simplified view of the process concerned. A key to the symbols used is given in Figure 1a. This shows the dependence of the end product on the professional cartographer's expert judgement in using libraries of cartographic symbols and the like.

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The prime feature of O.S. 1:50000 maps is the road network and this is obtained for by photographic methods from larger scales to form the framework of the new map. This is then redrawn in a style suitable for the new scale according to the cartographer's judgment. The remainder of the map is then constructed by a carefully assessed selection of the remaining features which are adjusted where necessary to fit and to give the "right" impression.

Automated approach. If the generalisation process is to be successfully automated it is clear that it must be fully understood in order that it can be turned into computer managable form. To attempt to do this we took Figure 1 as our starting point and generated a "Data Flow Diagram" (DFD) (Weinberg, 1980) of the equivalent automated processes involved (Figure 2) for programming into the computer.

It is in the computer equivalent of the photo-reduction process that there has been most work. The Douglas-Peuker algorithm (Douglas & Peuker, 1973) in particular derives the most characteristic generalisation of linear features and is particularly suited to the generation of strip trees (Harris, 1981). It envisaged that these techniques would be applied to the reduced linework at the target scale.

Other approaches to map generalisation. The generalisation problem is particularly challenging for the Ordnance Survey because of the legacy of established map series and the reference data supporting them. Countries mapping large areas accurately, possibly for the first time using modern techniques of photogrammetry and remote sensing have the opportunity to create styles which can cover all maps from about 1:10000 downwards. This does not trivialise the representation or the generalisation problem but it does make the process more amenable to hard logic rules.

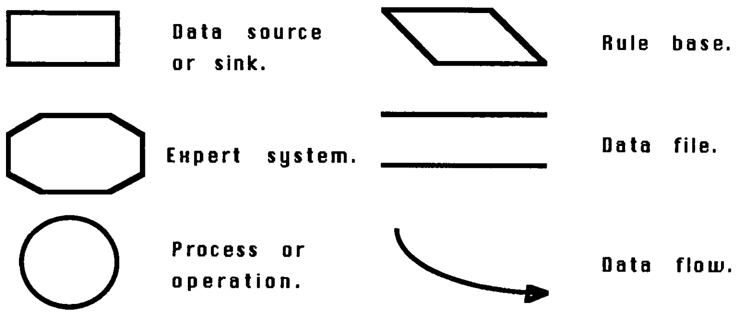

Figure 1a. Key to Data Flow Diagrams.

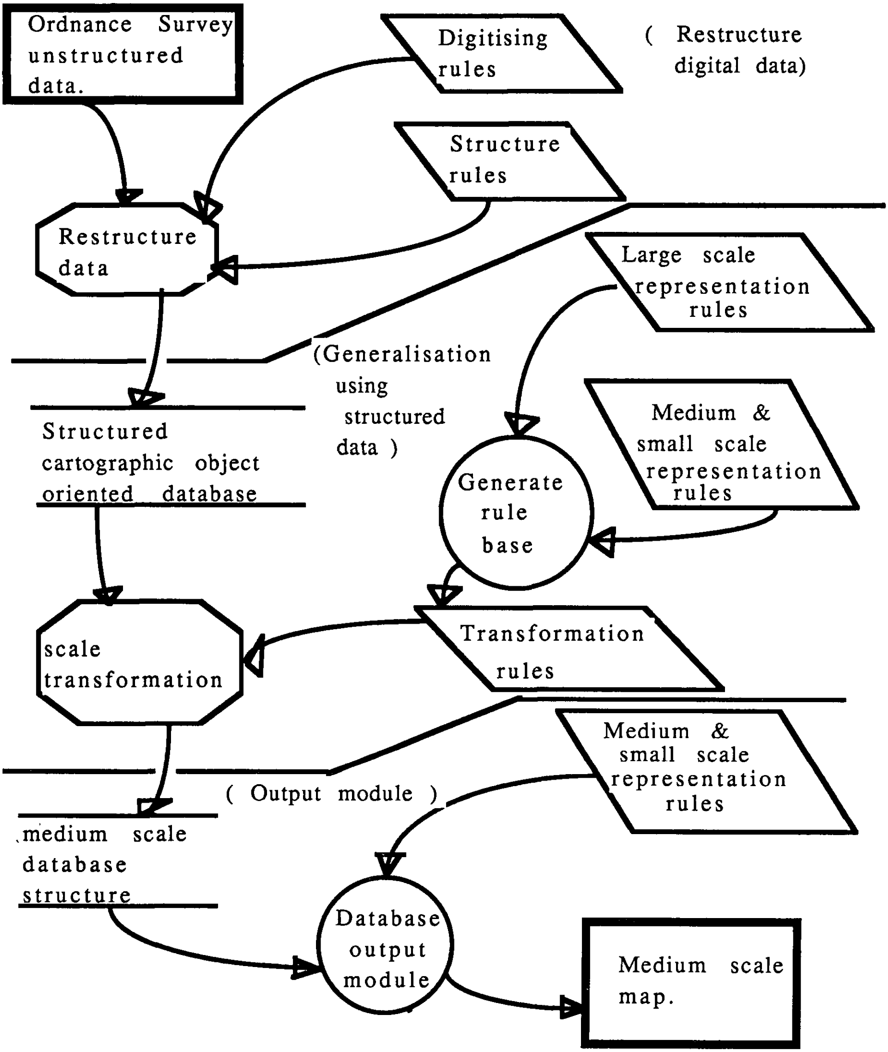

Figure 2. Data Flow Diagram of scale reduction using expert systems structure.

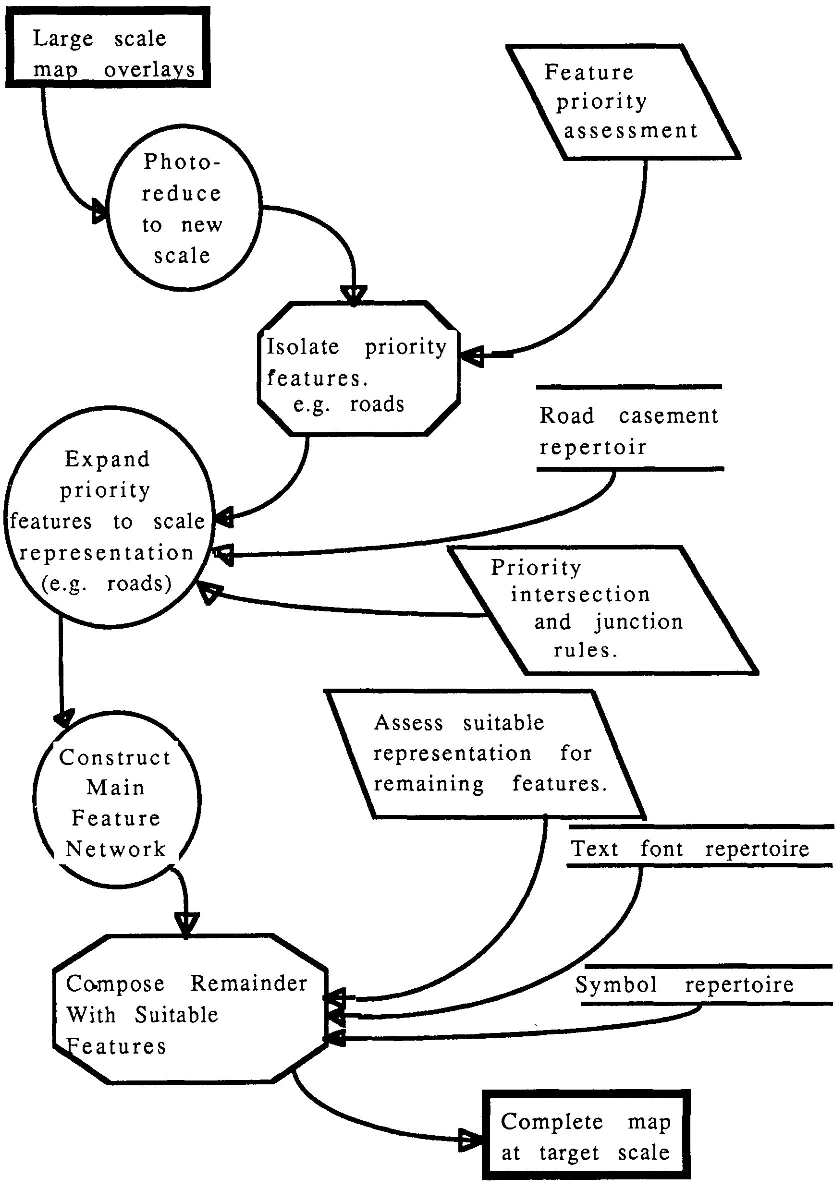

Figure 1b - Data Flow Diagram for manual scale reduction with generalistion

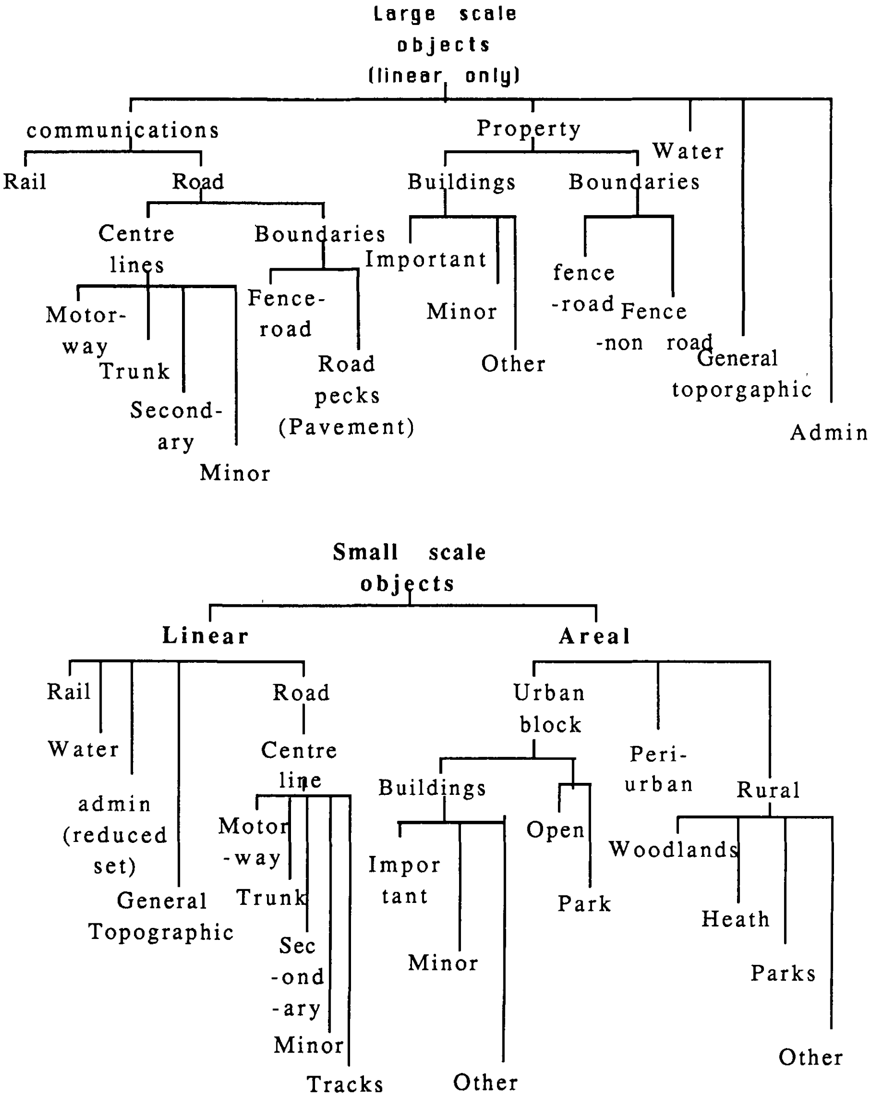

Figure 3. Map data structures at large and small scales.

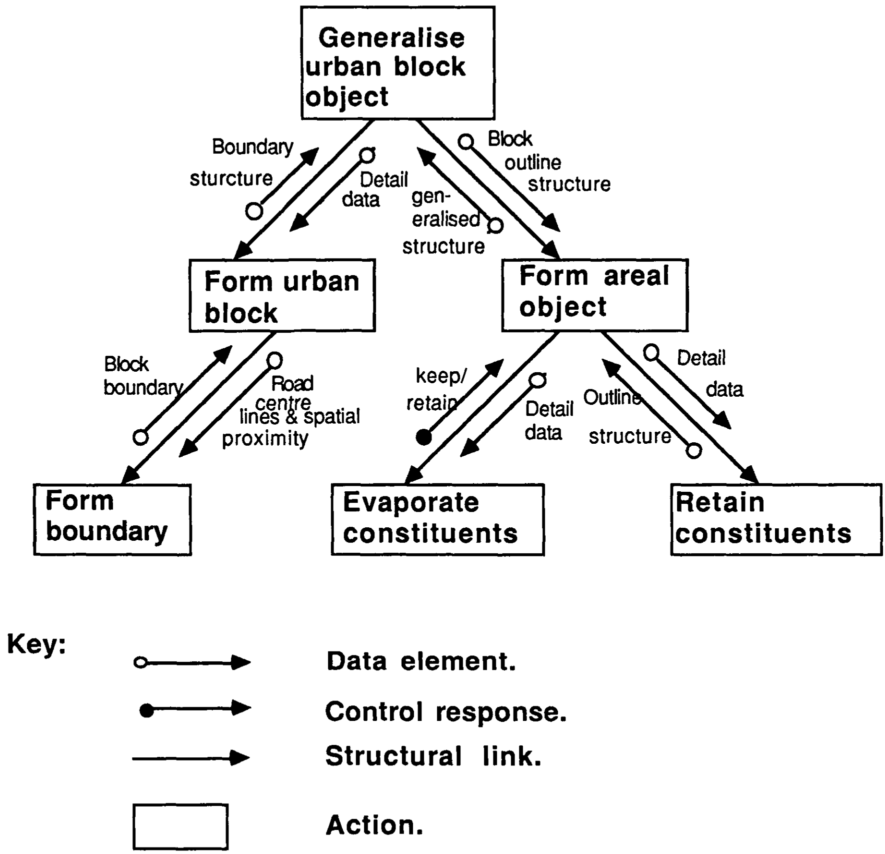

Figure 4. Transaction Analysis diagram for transform of an urban block.

concerned with the application of rules, fuzzy or otherwise, which map these objects and as a by-product their representations, into new objects at the target scale. One consequence of this approach is that objects, however defined, reflect the generalisation rules that operate on them.

Turning now to the rules we identify three basic types:

i) those that apply to basic objects. e.g. an object appears at one scale but not at another.

ii) those that modify the spatial and symbolic representation of an object.

iii) those that govern the spatial and symbolic aggregation of groups of objects into new objects.

The first set may be thought of as simply filtering the data by feature. Similarly the second could use existing line and area generalisation algorithms to filter the spatial representation of objects. The third set is the most difficult to handle and is the focus of most of our effort to date.

Object generation. By considering those objects present for the same area at different scales it is apparent that new composite objects are present at the smaller scale. The rules for composition of these are similar for both urban and rural areas although the former is the more complex. The assumption made is that the structure of the O.S. 1:50000 series is based on the road network and the remaining features are adjusted to fit the representation at this scale. Only the process for constructing an urban block is discussed here; the process for rural areas are very similar but slightly simpler. The structure of the data at both large and small scales is shown in Figure 3.

The process of transformation applied to urban data. The rules of representation at the source and target scales are well defined (Harley, 1973) and a correspondence is set up between them, the structures being defined so as to determine the creation of objects at the smaller and the treatment of their constituents from the larger scale. This defines the rules for collection and assembly into objects at the target scale. For instance an urban block at O.S. 1:50000 is defined by a combination of the application of administrative boundaries and the density of urban objects at the detatiled level of the larger scale. It containes essentially only three types of areal object; general housing, open spaces and parks, their boundaries being generated by approximation from the larger scale data. Exceptions are the presence of special buildings which are placed and presented as accurately as possible at the expense of the remaining data if necessary.

Detailed low level processing. Spatial referencing and road type information present in the O.S. digital data are used to assemble all road features to define the block and a centre line constructed. Features such as pavements and dual carriageway outlines are taken into account at this point.

Our approach. Several points from the preceding section are immediately obvious. Firstly Figures 1 and 2 are generalisations in themselves. Secondly current research on automated methods have concentrated almost exclusively on the low level spatial properties of the data forming the map. Thirdly few hard and fast rules are present, the majority are a matter of judgement in the manual case and loosely defined or "fuzzy", in the automated case. This indicated to us at an early stage that straightforward programming techniques would not suffice - a way of describing the "fuzzy" nature of the algorithms involved was essential. We therefore decided to investigate the variety of tools available in the area of Artificial Intelligence, in particular "Expert Systems". Current work has therefore centered on the use of an expert system (E.S.) shell (POPLOG) that was already available at Reading University, and which provides many features such as E.S. skeletons, LISP, Prolog, graphics and interfaces to other procedural languages.

GENERALISATION USING EXPERT SYSTEMS

The map as a hierarchy of objects. The availability of base data in a fully structured form with access to all relevant attributes is crucial to any attempt to model the generalisation process. As mentioned previously current techniques tend to be centred on the detailed lower levels of the map data rather than with high level objects. Our approach is based on that taken by the cartographer- predominantly top down - modified by occasional iterations at various levels. We thus start with the process:

Generalise (Map1 at scale 1 -> Map 2 at scale 2)

and commence to decompose this by breaking down the map into its component objects at the next level down. At large scales this could be into rural, peri-urban and urban areas. Each peri-urban and urban area object is broken down further into block objects delineated by the road network. These blocks could contain lower level objects such as houses and gardens, public buildings, parks, works, water bodies, etc. This process can be continued until the lowest level of object corresponds to the O.S. "feature". It is for this reason that fully structured data is required.

Restructuring Ordnance Survey digital data. The format of the digital data currently available was based on the ideas current in the early seventies which can be restructured with modern cartographic database software using spatially referenced attribute records and facilitates the restructuring process. The method being to bring together, spatially, the possible objects to which any line could be a component. Inference derived from the digitising standards would be applied to generate the attributes necessary for the component to fulfil all its functions.

THE GENERALISATION PROCESS

The object oriented view. Our technique is independent of the issue of feature representation. What we are doing is describing the map by a hierarchical object structure peculiar to each scale. The process is

The objects which comprise a block are generated and combined to form one of the composite features at the new scale and a boundary constructed between them. This will be modified however by the presence of special features, usually significant buildings, whose outline and position will be as exact as possible subject to modification from a generalised road boundary. This process produces a structure appropriate to the new scale and style which is the output by a specialised output module. These steps are represented in figure 2. The block translation procedure is represented by the transform analysis diagram in Figure 4 (Weinberg, 1980).

CONCLUSION

We consider that the above represents a fresh view view of a long standing problem central to the issues of the automation of cartographic design, albeit in a highly specific area, and a promising research project. There are also potential applications to data structures and datatransfer standards for medium and small scale maps.

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