This paper intends to discuss the nature or essence of digital map generalisation. Existing work is examined and new views are expressed. First of all, the motivation of generalisation is discussed. It is then grouped into two types, i.e. direct and indirect motivation and it is argued that scale is the only element in direct motivation. Based on this argument, two fundamental processes in digital map generalisation are distinguished, i.e. transformation of reality in scale dimension (digital data generalisation) and digital-to-graphic transformation (graphic presentation). Finally, a framework is devised for both of these two processes.

From phenomena to essence: envisioning the nature of digital map generalisation

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INTRODUCTION

In recent years, research in the area of digital map generalisation has become very active. Numerous papers have been published and new methodologies developed so that the literature in this area has been greatly enriched. One of the significant developments is the publication of a book by the American Association of Geographers, authored by McMaster and Shea (1992). This leads some optimistic researchers to claim that "our understanding of the generalisation process is now matured" so that conditions are ripe for an automated system to be built (McMaster and Shea, 1992, p121).

However, Robinson (1993) has a different view. He states that "the fundamental basis of generalisation at a theoretical level has recently been questioned (Brassel and Weibel, 1988). This highlights the growing belief, at least in the academic community, that generalisation is still not understood well enough to enable completely automated solutions to be developed, and that the entire process should be looked at carefully" (p4).

A recent study by Rieger and Coulson (1993) approves the view of Robinson (1993). In their study, Rieger and Coulson (1993) try to investigate how well expert cartographers understood the concepts of map generalisation. Eleven terms frequently appeared in text books and papers used in their study. A group of twenty-three 'expert' cartographers from North America was interviewed. This group included both academically and technically trained cartographers employed by universities, government mapping agencies and private mapping companies. It is found that "The declarative knowledge of this group of cartographers about generalisation is unstandardised in both the definitions of the procedures which make up generalisation and underlying concepts. Of the eleven terms for the procedures which were taken from the cartographic literature, the terms were not defined in the same way by all the experts and a few were not understood at all" (Rieger and Coulson, 1993). They then conclude that "further research is necessary into how cartographers understand generalisation, and the terminology of generalisation . . ." (p69).

Indeed, it is these recent studies that make the authors reassess the current situation of how well the nature or essence of digital map generalisation is understood and discuss this fundamental problem. In this paper, first all, examples of the chaotic phenomena of map generalisation are given. Following this is a discussion of the motivation behind map generalisation. Based on this discussion, a framework for digital map generalisation is proposed.

THE PHENOMENA

Map generalisation, unlike the mathematical optimisation problem, has no objective function but a series of intuitive and artistic guesses as to the most appropriate solution. As a result, map generalisation, on the surface, appears to be a chaotic process and the chaotic phenomena can be illustrated by the following two examples:

João et al (1990) have illustrated the consequence of generalisation of the representation of a town (Portee of Scotland) displayed at different map scales. At a 1,250 scale map, the layout of individual buildings and plots (including fences) can clearly be seen. At the 1:10,560 scale map, the buildings are represented by areas but the finer details are now lost. At the 1:50,000 scale, however, only groups of buildings joined to form contiguously built-up urban regions can be seen. At the 1:250,000 scale, the entire town is represented by a single area polygon. Finally, at the 1:625,000 scale, the whole town is represented by a single point" (Li and Openshaw, 1993).

Müller (1990) has made a comparative analysis of German topographic maps at 1:25,000 and 1:200,000 scale. He notices that "all kinds of transformations have taken place. Rivers, rail tracks and main roads have been widened; streets and smaller roads have been eliminated: individual buildings have disappeared or have been regrouped into geometric square sided symbols simulating built up areas; most of the contours have been removed; a few landmarks are retained and are highly symbolised; some selected land use areas are circumscribed by polygons and enhanced whereas others are simply annotated by a graphical symbol" (Müller, 1990).

Yes, this subject as whole might be compared to the classic story about the appearance of an elephant told by blind persons. Therefore, there is a possible danger that only parts of its body have been touched and our current understanding is still not as comprehensive as it is thought by many. Indeed, this line of thought is another element which makes the authors conduct this discussion.

THE MOTIVATION

To tackle this complex problem, it might be beneficial to start with a discussion of the motivation behind generalisation.

Müller (1991) considers that generalisation is promoted by four main requirements:

- Economic requirements;
- Data robustness requirements;
- Multipurpose requirements; and
- Display and communication requirements

In a more detailed manner, McMaster and Shea (1992) identified three sets of "philosophical objectives (why to generalise)" as follows:

- Theoretical elements:
  # reducing complexity;
  # maintaining spatial accuracy;
  # maintaining attribute accuracy;
  # maintaining a logical hierarchy; and
  # consistently applying generalisation rules
- Application-specific elements:
  # map purpose and intended audience;
  # appropriateness of scale; and
  # retention of clarity
- Computational elements:
  # cost effective algorithms;
  # maximum data reduction; and
  # minimum memory/disk requirement

This classification tends to be more computeris appropriate for action and appears to be more complicated. By contrast, Müller's set is more general. It seems to the authors that some kind of abstraction needs to be applied to these lists so that the problem can be simplified and useful models established. This kind of simplification is vital in scientific research. The classic example of such a simplification is the Earth being simplified by Newton as a point so that the beautiful Law of Gravitation could be established.

Indeed, such a simplification in map generalisation has already been made. As cited by Müller (1991), the Swiss Society of Cartography has long ago made it clear in its cartographic manual that generalisation is motivated only by a reduction of scale although this view has been considered by Müller (1991) to have over-emphasised the display and legibility constraints in map production. However, as will be discussed later, there is no fundamental contradiction between these views.

In fact, it is the view of the authors that there are two types of motivation behind map generalisation. One type is direct motivation and the other type is indirect motivation. Scale is the only element in direct motivation while indirect motivation includes all those identified by Müller (1991) and some by McMaster and Shea (1992). This kind of relationship is illustrated in Fig.1.

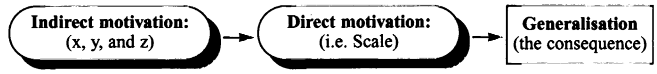

Figure 1. Relationship between two types of motivation for generalisation.

THE ESSENCE

In the previous section, the motivation is discussed. This section will discuss the nature or essence of map generalisation.

From the literature, it can be found that there are different views on map generalisation. For example, Müller et al (1993) have distinguished two types of issues in map generalisation as follows:

- modelling generalisation, which is viewed as an interpretation process leading to a higher level view of some phenomena; and
- cartographic generalisation, which deals with graphic representation.

As has been argued in the previous section, generalisation is driven by scale. So map generalisation is in fact a process of transforming reality along the scale dimension as discussed by Li (1994). This should be an objective process and it can be implemented by mathematical solutions based on the natural principle (Li and Openshaw, 1993). The view that the map generalisation process is a modelling process is only an interpretation of purpose but not the essence.

Of course, one may argue "what about displacement, exaggeration, etc?" Yes, these are about graphics. It is due to the limitation of graphic resolution. In manual generalisation, everything is done in one single process to make the process appear to be very subjective. Of course, this subjectivity is also caused by the consideration of the "characteristics and importance" of features as pointed out by Keates (1989). On the other hand, in a digital environment, data resolution could be infinitely high, theoretically speaking. For example, two lines with much less than 0.01 mm are still separable in a digital database. Only after a graphic representation is considered, then come the problems of displacement and other complex operations. Therefore, digital map generalisation is a two stage process and this process can be illustrated in Fig.2. Graphic representation is actually a process of digital-to-graphic transformation.

Figure 2. The process of digital map generalisation.

After transformation of reality in the scale dimension, spatial reality in a form of digital data is generalised (simplified). Therefore, this process can also be *refered* to as digital data generalisation. The relationship between manual and digital map generalisation can be illustrated in Fig.3.

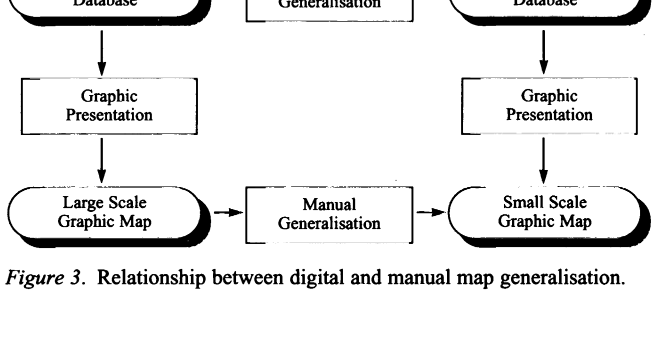

Figure 3. Relationship between digital and manual map generalisation.

Since reality transformation in the scale dimension is a process of digital data generalisation, so it should be possible to be processed by a mathematical solution in the form of a batch file. Graphic presentation is a process involving artistic skill and therefore it might need an expert system for assistance.

CONCLUDING REMARKS

In this paper, it has been argued that

- The direct motivation behind any map generalisation is scale although there may be many other elements included in indirect motivation;
- Map generalisation in a digital environment can be decomposed into two stages, i.e. digital data generalisation and graphic representation.

Digital data generalisation should be possible to implement using mathematical solutions based on the natural principle (Li and Openshaw, 1993) in a form of batch file. Graphic representation is a process involving artistic skill and therefore it might need an expert system for assistance.

This discussion is another paper regarding the appearance of "the elephant" of map generalisation. It is the authors' hope that this discussion will, in some way, contribute to the true picture of "the elephant". The remaining problem is to develop new paradigms based on these views.

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