*This paper is an attempt to provide a view point for the formalisation of knowledge in cartographic representation. What is supposed to be reality in the world is dependent on time and scale. So, there are different levels of reality, from low to high. Cartographic representation is a graphical record of reality at a particular location in the time-scale system. The problem of the transformation of reality in both scale and time dimensions in this time-scale system is also briefly discussed.*

# Reality in time-scale systems and cartographic representation

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## INTRODUCTION

It is currently a fashion to talk about 'knowledge-based systems' in various scientific disciplines. Digital cartography is no exception. In the early 1980s, such systems had already been under development (Nickerson and Freeman, 1986). Further research papers have been published in the 1990s (Ogrosky and Roth, 1990; McMaster and Mark, 1991). Special sessions on this topic have been organised in relevant conferences (for example, the recent 16th International Cartographic Conference held in Cologne, Germany) and a special symposium on this topic was also organised by the NCGIA in 1990 (Buttenfield and McMaster, 1991). To develop a knowledge-based system, the first step to be taken is to formalise knowledge of cartographic representation. To do so, the following two questions need, first of all, to be answered:

(1) What is to be formalised? and

(2) How can we formalise it?

So far, the answers to these two questions are, in most cases, sets of 'if-then' statements (exceptions include Müller, 1989). These answers are obtained, sometimes based on particular set of maps, sometimes based on the particular authors' experience. While these particular case studies or particular experience are important in practice, it is desirable to produce an insight into the theoretical aspects of cartographic representation which could then be used as a guide for formalising knowledge of cartographic representation. This paper is an attempt to provide a view point for this purpose.

In this short article, a discussion of the concept of reality in general is first of all given, followed by a discussion of the variation of reality with scale and time. A time-scale system is introduced for the representation of reality and finally, the transformation of reality in time-scale systems is also briefly discussed.

## DIFFERENT LEVELS OF REALITIES TO BE REPRESENTED

The concept, reality, should refer not only to those phenomena which can be observed physically but also to those whose existences are beyond one's imagination. Therefore, there are different levels of realities, from low to high.

The lowest level of reality could be the existence of those objects which one could observe daily. The existence of a building, a street, a city, and so on are examples of low level realities which could be realised easily. An event in daily life and some similar processes are at a higher level. Events like a car moving on a road, water running in a river, an election campaign carrying on, and processes like soil erosion, are examples which are still easy to understand. Some other, high level, reality in this world, only professionals could understand well. For example, the population migration pattern of a city, the economical problems of a country, and so on are beyond the gasp of ordinary persons without any proper professional training.

What is described by scientific laws could also be realities and also with different levels from low to high. The realities described by Newton's laws of motion have become easy to understand because these can be recognised, but Newton's law of gravity, which describes another level of reality, becomes more difficult to imagine for those who are not good at physics. Furthermore, some of those realities described by Einstein's theories and/or laws are not only difficult to realise but also difficult to imagine even by physicists. $E = mc^2$ describes a reaction which is almost unbelievable but does exist at least in the domain of nuclear fission.

So, there are different levels of realities in this world. Some are to be represented by topographic maps, some by thematic maps, some by charts and some by diagrams. Also some are easy to realise while others are more difficult. Therefore, some are easy to be represented cartographically while others demand imagination such as the representation of realities in very small scale maps.

## VARIATION OF REALITY WITH SCALE AND TIME

*Figure 1* is an example showing possible variation of reality with scale. This point could be further clarified by considering physical objects which appear differently on viewing from different distances. If the Earth is viewed from infinity, it should appear to be a point. This is a level of reality in the macro world. If it is viewed from the moon, it can appear like a blue ball. This is another level of reality.

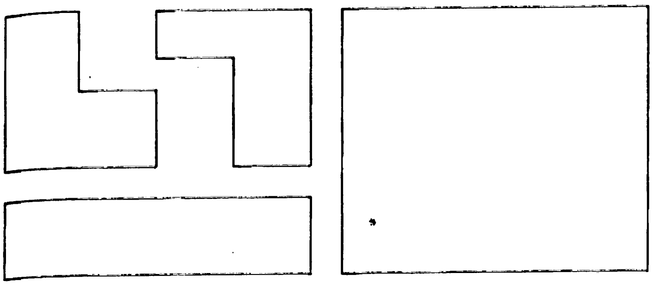


*Figure 1.* Variation of reality with scale.

If it is viewed from a satellite, the variation on the Earth's surface is very gentle and highways may be detected. This is another level of reality. If it is viewed from an airplane, very many details of the Earth's surface can be observed and even small roads can also be identified. This is yet another reality. If an observer stands on the highway, then the roughness of the highway surface could also be observed clearly. These realities are of great interest to cartographers.

If the highway surface is viewed with some magnification, then the holes and hollows on the surface are exaggerated. If a very powerful electronic microscope is used, the atomic structures of surface materials might also be seen. This is yet another level of reality, but in the micro direction of the scale dimension. (These realities are of interest not to cartographers but to physicists, and scientists in other fields.)

It is also clear that, based on different study units (i.e. scales) one may get different statistical results when analysing social-economic data (Openshaw, 1984).

What is supposed to be reality is dependent on scale. It can also be illustrated that what is supposed to be reality is also dependent on time. For example, at a particular time land may have been agricultural. However, recently a motorway could have been built through this area. Also with soil erosion, the landscape could be gradually changed.

## REALITY IN TIME-SCALE SYSTEM AND CARTOGRAPHIC REPRESENTATION

Reality is multi-dimensional while the cartographic media is only two-dimensional. Therefore, one has a problem in representing reality cartographically.

In addition to scale, time could be considered a further dimension to existing 3-dimensional space. Such a multi-dimensional system (five dimensions) can then be decomposed into two, a time-scale system and the ordinary 3-D space. So every reality could be considered as an 'event' in the time-scale system, as shown in *Figure 2*. The origin of the time-scale system could be considered to be at (present, 1:1). In the time dimension, one direction is towards the past and the other towards the future. In the scale dimension, one direction is towards the macro scale while the other towards the micro scale. The reality in any location of this time-scale system could a 3-D object with the third dimension representing terrain height, population, and so on. At different locations in this time-scale system, the reality is different. A cartographic representation is only a record of a reality at the particular location in this time-scale system.

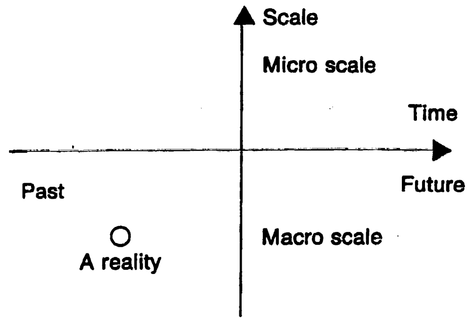


*Figure 2.* A reality in a time-scale system represented in a map.

## TRANSFORMATION OF REALITY IN THE TIME-SCALE SYSTEM

What is of particular interest to cartographers is the transformation of a reality in this time-scale system. One specific characteristic of such a transformation is that it is not necessarily reversable. If the reality represented on an old map is the existence of low level realities such as buildings in a city, then the transformation could be sudden or catastrophic, similar to those discussed by Müller (1989). However, if the reality represented on a map is a higher level of reality such as soil erosion, then the transformation could be continuous.

The transformation of reality in the time dimension is studied by so-called 'temporal modelling'. Cartographic representation of the transformation of reality in the time dimension is accomplished by map updating.

The transformation of reality in the scale dimension is conventionally studied by map compilation, particularly map generalisation. In this area, there is still no comprehensive theory as a guide. The current trend is to use a rule-based approach, but this may create new subjectivity and produce more inconsistent results. Alternatively, Li and Openshaw (1990) have suggested using the so-called natural principle as a guide in order to reach more objective generalisation.

## CONCLUDING REMARKS

By introducing this time-scale system and the concept of transformation of reality in both scale and time dimensions, it is hoped that the problems in cartographic represention can be more easily envisaged; some sort of mathematical notation could then be more easily introduced; and thus, the goal of objective generalisation could more easily be reached.

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