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Proceeding I

Proceeding II

PREFACE

The call for papers for the 16th ICC'93 in Cologne met with such a good response and attracted such a large number of qualified papers that the Organizing Committee of the Conference decided to expand the program: A poster session offers the opportunity for visual presentations of additional papers, and a specific "information market" makes it possible to present workshop results at short notice. The papers of the oral presentations and as well as the contributions to the poster session are compiled in this publication which had to be split up into two volumes because of the large number of papers submitted and eventually accepted for presentation.

It would not have been possible to complete this publication without the support and cooperation of many people. First of all, we have to thank the autors who contributed to the publication by handing in their papers in time. According to the regulations of ICA, the texts are in the official ICA languages, i.e. either in English or in French; they are in their original form and have not been edited.

All papers were rewiewed by the members of the Scientific Programme Committee who also gave their advice, and contributed to the organization of the programme for the plenary and poster sessions. I gratefully acknowledge the help rendered by

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The general theme of this conference covers a wide variety of cartographic subjects. The Scientific Programme Committee expects the Cologne ICC'93 to answer - many or at least some - questions, but we are also sure it will raise new ones. We hope that the publication of the proceedings will promote discussion and contribute to the dissemination of cartographic knowledge and hence to progress in cartography.

Peter Mesenburg
Chairman Scientific Programme Committee

Note: The proceedings contain only those papers that were received in time for publication

Session 14

Map Based Information Systems III

Chairman:
Q. Zhang, Research Inst. of Surveying (Beijing, RC)

The use of colour in the cartographic representation of information quality generated by a GIS

A. Brown, C.P.J.M. van Elzakker (Enschede, NL)

ABSTRACT

Bertin's systematic approach to symbol design is reviewed with special reference to its possible use in communicating to the user of a GIS quality information at the same time as attribute information, in cartographic form. The discussion leads to the hypothesis that the visual variables of colour can be used in the case of categoric area information, with the variable hue used to represent the category and the variable saturation to represent the quality of the information. Experiments were carried out for a particular combination of a GIS and an inkjet printer. It was found to be much easier to vary saturation independently on a display screen than on printer output. On the printer output, however, lightness value could be made to vary to reinforce variations in saturation. With the help of colour charts, it is concluded that the simultaneous representation of attribute and quality is possible for categoric area information, for both screen display and printer output, but for a limited number of categories and quality levels.

Introduction

In recent years more and more attention has been paid to the quality (or accuracy or uncertainty) of data stored, manipulated and processed within geographic information systems (GISs) and to the quality of information generated by those systems. In the literature, acceptance is found of a fivefold classification of geographical data and information quality into: spatial quality, attribute quality, completeness, logical consistency and lineage.[1]

It is important that the users of a GIS are informed about each of these quality aspects in order to improve their decision-making with the help of a GIS.[2,3] Quality information may be conveyed to the GIS user by textual, numerical or graphical means. Non-cartographic means will have to be used only if there are no regional variations in quality or if these variations are or cannot be specified, as is often the case for information on completeness or logical consistency. If quality information on positional and attribute accuracy (and possibly on lineage) is available for individual mapping units and there is some regional variation in it -as is often the case- this information can be very effectively represented cartographically, as maps are the most efficient means of communicating geographic information.[1]

This paper focuses on the cartographic representation of quality aspects related to data held in and information generated by a GIS. Attention will be paid first to the cartographic representation of quality information in general and, thereafter, to the specific use of the visual variables of colour in particular. The actual use of these visual variables is influenced very much by the anticipated means of cartographic output, being either the display screen of the GIS computer configuration or the hard copy paper. The article is concluded by a report on some practical experiments which have been carried out on the use of colour variables in the cartographic representation (on display screen and on paper) of categoric area information and its quality differences, leading to some guidelines on the variation, alone or in combination, of the saturation, hue and lightness value of the cartographic area symbols generated in a GIS environment.

The cartographic representation of quality information

In a GIS quality information with a spatial (geographical) component can be stored, analysed, processed and presented just like other attribute information related to point, line and area features. As far as the cartographic representation is concerned, the same symbol design principles apply as for other aspects of information. Therefore, use can be made of the systematic approach to symbol design presented by Bos[4], and initially introduced by Bertin[5], based on the relationship between the measurement level of the information and the perception properties of the visual variables applied to the cartographic symbols with which that information is going to be portrayed.

Three measurement levels are distinguished: qualitative (nominal, or sometimes referred to as categoric), ordered (ordinal) and quantitative (interval and ratio). For cartographic representation, the distinction between relative and absolute quantitative information is relevant as well (Figure 1).

Measurement levels of geographic information

Qualitative	=	information about the different nature / identity of things
Ordered	=	information with a clear element of order, though not quantitatively determined
Quantitative	=	information about specified amounts
Absolute quantities	=	observed, measured or counted quantities (e.g. number of inhabitants, tons produced)
Relative quantities	=	calculated, derived quantities (e.g. densities, ratios, percentages)

Figure 1. Types of mappable information

The essence of cartographic symbol design is that these different kinds of information are represented by means of visual variables with specific perception properties: association, order and quantity respectively (Figure 2). There are seven visual variables (position, form, orientation, colour, texture, value and size), each with its own perception properties (Figure 3). The visual variables with a quantitative or an ordered perception property have a selective perception property as well, but not all associative visual variables are also selective.

The first step in a systematic approach to the design of cartographic symbols to represent quality information, like any other geographic information, is thus the establishment of the measurement level. Information on (regionally different) data sources (for example part of a data set's lineage information) could be considered to be of a qualitative nature and thus should be represented by means of a visual variable with an associative perception property, for instance form or orientation. Other examples mentioned in the paper of van Elzakker, Ramlal & Drummond[1] include the representation of ordered attribute accuracy information by means of the visual variable lightness value and the representation of absolute positional discrepancies by means of the visual variable size (error ellipses).

INFORMATION	represented by a visual variable with	PERCEPTION PROPERTY
Quantitative (absolute)	--------------------->	Quantitative
Quantitative (relative)	---------------------->	Ordered
Ordered	-->	Ordered
Qualitative	------------------------------------>	Associative (± selective)

Figure 2. Essence of cartographic symbol design

	Position	Form	Orientat.	Colour	Texture	Value	Size
Associative	+	+	+	+	0	-	-
Selective	-	-	0	++	+	+	+
Ordered	-	-	-	-	0	++	+
Quantitative	-	-	-	-	-	-	+

Figure 3. Perception properties of the visual variables (source: Bos, 1984)
(++= very good; += good; 0 = moderate; - = poor/no)

In this way it is easily possible to generate sound analytical cartographic displays of quality information. However, for GIS-users this quality information is normally only relevant when directly related to the geographical (attribute) information to which it belongs. This means that the GIS output should allow a visual integration of quality and attribute information, for instance by means of a "quality overlay", which may be switched on and off (or "toggled") on-screen by the GIS-user at will.[1] It is also possible, however, to represent both the quality and the attribute information with different visual variables combined in one set of symbols, which is practical as the locational references of both related aspects of information are the same. It is especially in this latter "bivariate mapping"[6] situation that the application of the visual variable colour may yield good results.

The visual variables of colour

In the previous paragraph "colour" was mentioned as one of the seven visual variables. However, in practice, the application of this variable may lead to some problems as a consequence of the fact that colour sensations result from the combination of the aspects of hue, lightness value and saturation. These three independent variables in our perception of colour are sometimes also called hue, value, chroma, or (especially for computer display screens) hue, intensity, saturation respectively.

Hue is what we mean when we refer to colours by names such as red, orange, green, purple, etc. A more scientific definition is: the visual stimulus provided by a dominant single wavelength, or by dominant mixtures of wavelengths, or by the absence of particular wavelengths emanating from a coloured area.

In fact, hue difference only is what is meant when reference is made to the visual variable "colour" in Bos' systematic approach to symbol design. This visual variable has an associative perception property (i.e. when applied to a set of symbols, all symbols, though characterized by a different hue, are perceived as being equally important; no one symbol stands out above the others) and a very strong selective perception property as well (i.e. if not too many different hues are used, in the map the eye can immediately isolate groups of symbols with the same hue). Therefore, this visual variable can indeed be used very effectively in the cartographic representation of qualitative information, for example differences between soil types in a soil map (i.e. categoric information) or differences between data sources in a cartographic representation of data quality (an aspect of lineage in this case).

Lightness value, the second colour sensation, is also mentioned as one of the seven visual variables in Bos' systematic approach to symbol design. This visual variable refers to the relative lightness or darkness of a symbol, compared with the standard values of a grey scale. If we refer to a hue named "red", for instance, and keep that hue constant, we may create a lightness value difference from light red to dark red by applying various percentage tint screens. Lightness value may also be denoted as reflectance value, i.e. the amount of light being reflected by any given symbol.

The visual variable lightness value has ordered and selective perception properties (i.e. when applied to a set of symbols, these can spontaneously be placed in an order of magnitude, for example from low to high, or from least to most important). Therefore, this visual variable may very well be used to represent ordered or relative quantitative information. Examples are the cartographic representation of soil suitability for a particular crop ("the darker the more suitable") or the representation of differences in reliability of soil suitabilities (expressed by percentages as an example of quality of attribute information).

A complicating factor in cartographic symbol design is that different colours, i.e. different hues, may have different reflectance values, even if they are both solid or are printed with the same percentage tint screen. Brown, for example, will normally reflect less light than yellow.

Even more complicating is the fact that the third colour sensation, *saturation*, is usually disregarded in the systematic approach to symbol design. It is not included as a separate visual variable in the list of seven presented in the previous section, perhaps because it is the colour sensation which is most difficult to understand and most difficult to vary in practice. Saturation is the term given to describe the relative purity of colour in a given area. A full scale of saturation would have at one extreme the pure hue and at the other a neutral grey of the same lightness value. The saturation of any colour is the degree to which it departs from a neutral grey of the same value, and we vary the saturation by changing the ratio of grey and hue in a given area. In very simple terms we can vary the saturation of a given hue by adding white to it, but as this will also affect the lightness value, more correctly we should add different proportions of grey. As de-saturation proceeds, we will eventually reach a stage where no trace of hue remains and we are left with a neutral grey. Note here that a percentage tint of a printing colour is not only *lighter* than the full printing colour, but also less saturated.

Disregard of saturation in the systematic approach to cartographic symbol design can give rise to problems, particularly when cartographers have to design maps on display screens as well as on paper. The following sections report on experiments with the application of saturation, as well as the other two visual variables of colour, in the cartographic representation of quality information, both on display screens and on paper. In the experiments we have restricted ourselves to categoric area information for two reasons: in the case of point and line symbols, the use of the visual variables of colour is very limited, since very large colour differences are necessary for good discrimination[7]; secondly, the combined use of lightness value and saturation to represent ordered or relative quantitative information and its quality in the same set of area symbols has proved to be difficult to perceive[6].

The visual variables of colour and their use in display screens

Several systems for colour matching or colour specification are based on the variables hue, lightness value and saturation as discussed in the previous section. The best known of these for object colours (reflected light) is probably the Munsell system. Different systems have been devised for use with the emitted light of display screens, in which colours are produced by the additive mixture of red(R), green(G) and blue(B) glowing phosphor dots. These colour specification systems do not follow a single standard, and colours specified in one system can not always easily be transferred to another system.

Some systems use a very simple method to calculate the hue. In a RGB triad of phosphor dots the excitation level or intensity value of the dullest dot is subtracted from the intensity values of the other two. The ratio of the resulting two numbers indicates the hue. When, for example, RGB can have intensity values from 0 to 255, then a colour with R100, G180 and B120 has the same hue as a colour with R50, G150 and B75. In many colour specification systems, hues are regarded as being spaced around a circle. A formula has to be used to convert the intensities of RGB into an angular measure. In these systems, therefore, colours with the same hue have the same hue angle, and complementary hues are diametrically opposite.

The variable lightness value gives rise to some problems. In some systems it is simply the sum of the intensities of RGB in a triad. This takes no account of the differing sensitivity of the human visual system to different wavelengths. On a display screen, an area of green dots, for example, will appear lighter than areas of red and blue dots respectively, glowing with the same intensity. The Tektronix TekHVC colour model is adapted to this. It is derived from the CIE Uniform Colour Space and it gives a result very similar to the Munsell system, with for each hue a set of variations presented on a coordinate system with value along the vertical axis and chroma along the horizontal axis. All colours with the same *perceived* lightness have the same value.

The visual variable saturation (chroma) can most simply be regarded as the relative dominance of a particular hue. On display screens, the most saturated colours are produced when at least one of the three (R, G or B) dots of a triad is glowing with full intensity and at least one is not glowing at all. If all three are glowing with equal intensity the result is a colour on the achromatic scale of white through greys to black. An approximate method of calculating saturation is to subtract the intensity of the dullest dot from that of the brightest dot. However, many systems use more complex formulae to calculate saturation.

The fact that many different colour specification systems exist for use with display screens demands that a user of any particular GIS package has first to familiarise himself with the colour system employed. He also needs to be familiar with how colours appear on the screen he is using. The dyes used for the RGB phosphor dots are not of a uniform standard, so colours appear different on screens from different manufacturers. Even when using identical screens, colour appearance can vary very much according to how the screen is adjusted and to the ambient light conditions. Also important is the number of colours which can be displayed simultaneously. If the user wants to be able to use the colour variables freely, then he needs a system which can display a large number of colours simultaneously, for example 256 chosen from a larger palette of 16.78 million colours.

The large number of colours available on many GISs is an invitation to attempt to make subtle use of the colour variables. In the particular case of the integrated cartographic representation of categoric area information and its quality in the same set of symbols, it is possible to represent the category by the visual variable hue and the information quality by the variable lightness value. We considered that it might, however, be preferable to represent information quality by the use of the visual variable saturation, alone or perhaps combined with lightness value. For the mapping of ordered or relative quantitative attribute information it is common to use the variable value, i.e. "darker" means "more", as indicated in the previous section. To make a clear distinction between this convention and the representation of information quality, we suggest to use saturation as the only or main visual variable to represent quality.

A perceptually robust representation method is one in which misinterpretation by the user of the display, e.g. a planner, is at a minimum. If the visual variables of colour are used to convey information, the producer of the display has to be sure that these variables are always clearly perceived. He has to take into account the fact that the user may have a different type of screen, possibly not properly adjusted and possibly used in very different lighting conditions. Furthermore, induction effects can cause the same colour to appear different when adjacent to different colours. All of these factors taken together limit very severely the number of different hues which can be used in a single GIS display, and also the number of variations in lightness value and saturation for any single hue. If the GIS user wants to use the variable saturation as the main variable to represent information quality, he is likely to be limited to three or four classes. To increase the differentiation among quality classes and to allow for one or two more classes, the visual variable value may be used to reinforce saturation.

Printed output on paper

Often, the GIS user wants a hard copy on paper of a screen display. The transfer from screen to paper raises a whole new set of problems regarding colours. Most fundamental is that the screen use additive mixture of RGB, which is converted on paper to subtractive mixture of cyan(C), magenta (M), and yellow(Y), often with black(K) added. On the screen, the phosphor dots change in intensity of light emitted, not in size. On paper, CMYK dots of different sizes are used, overlapping each other. On the screen, 'zero colour' is black, while on paper it is white.

Take a typical situation in which screen intensities of RGB on a scale of 0 to 255 are converted to printed percentage tints of CMY on paper. On the screen, the most intense green, the colour R0, G255, B0, appears lighter than 'half' green, the colour R0, G123, B0. On paper, green is made up of equal tints of cyan and yellow. Full (100%) green, corresponding to G255 on the screen, consists of solid cyan printed on solid yellow. This appears *darker* than 50% green (corresponding to G123 on the screen), which consists of 50% cyan printed on 50% yellow.

At present, two main techniques are used to produce coloured paper copies of a GIS display. The most economical technique for producing very few copies is the use of a colour printer, of the inkjet or thermal transfer type. When a large number of copies is required, output has to be produced on a high quality raster film plotter, one film for each of CMYK, for offset printing. This second technique can be very precisely controlled and standardised. Tints of exactly the desired percentage can be produced on film, and one of several internationally standardised sets of CMY printing inks can be specified.

Output on inkjet or thermal printers is much more difficult to control and standardise. Different printers use different sets of CMY inks, and they use different "dither" patterns to produce tints. Printers typically can produce only a limited set of tints, whereas film plotters can produce any percentage tint. One important consequence of the limited number of dither patterns is that two colours which appear rather similar on the display screen can appear very dissimilar on the paper copy, and vice versa. Furthermore, the dither patterns are usually coarse, so it is possible to see the dot structure, unlike in the case of the very fine dot structure of offset printed copies from film output. The result of this is that the same digital file can give very different results on different printers, which are in turn very different from offset printed copies from film output. All of this puts yet another limitation on attempts to make subtle use of the visual variables of colour in conveying different aspects of information, particularly in combination.

An example of colour charts for use with a GIS

From the discussion so far, it is clear that in order for the designer of a GIS display to make as full use as possible of the visual variables of colour, he has to understand fully the colour specification system used in his GIS. He also should use a carefully calibrated display screen in standard ambient lighting conditions, connected to a limited number of hard copy output devices, and he should know exactly how screen colours 'translate' on each. An indispensable aid in this context is the production of colour charts. An example of this approach is described below.

ITC has developed its own GIS, ILWIS. This was judged suitable for colour display experiments, since it can display 256 simultaneous colours chosen from a palette of 16.78 million. Colours in ILWIS are specified in three different ways: RGB; the CMY equivalent; hue, saturation and intensity. Each of these nine values is expressed on a scale of 0 to 1000. For RGB, the original intensity scale of 0 to 255 is simply rescaled. The other 6 variables are derived using the formulae given below.

$$Cyan = 1000 - Red$$

$$Magenta = 1000 - Green$$

$$Yellow = 1000 - Blue$$

$$Hue = \frac{500}{\pi} \arctan \left(\frac{\sqrt{3}}{2} \times \frac{Green - Blue}{Red - \frac{Green}{2} - \frac{Blue}{2}} \right)$$

$$Saturation = \sqrt{Red^2 + Green^2 + Blue^2 - (Red \times Green) - (Red \times Blue) - (Green \times Blue)}$$

$$Intensity = \frac{Red + Green + Blue}{3}$$

The display screen used was a NEC/MultiSync 3D and the paper copy output device chosen for the experiments was the Hewlett Packard PaintJet printer. For each of the printer colours (CMYK), the printer can produce 11 tints. The complete set of tints for each of CMYRGBK was printed. They were measured using a Gretag model D186 densitometer, in terms of percentage tints of CMY (black for K). The result is given in Figure 4.

Two conclusions can be drawn immediately from this table. One is that the darker tint classes (8 to 11) are very close to each other. This is confirmed by visual inspection. The second is that the colours are not 'pure'. The yellow ink behaves as if it contains some magenta, the magenta ink behaves as if it contains some yellow and the cyan ink behaves as if it contains magenta and yellow. This is revealed also in the combined colours, RGB. Because both yellow and magenta appear to contain very little cyan, the combination, red, also appears to contain little cyan. Blue, however, contains a high proportion of the complementary yellow, and green contains a high proportion of the complementary magenta. The result of these impurities is that the full colours CMYRGB do not appear to be of equal saturation. The saturation sequence of the full colours from highest to lowest is Y-M-R-C-B-G.

Tint nr.	Cyan C M Y	Magenta C M Y	Yellow C M Y	Red C M Y	Green C M Y	Blue C M Y	Black
0	000, 000, 000	000, 000, 000	000, 000, 000	000, 000, 000	000, 000, 000	000, 000, 000	000
1	007, 003, 001	001, 006, 003	001, 001, 006	000, 009, 009	009, 010, 003	009, 004, 009	009
2	014, 006, 003	000, 013, 004	001, 003, 012	000, 017, 018	014, 019, 005	017, 008, 018	015
3	024, 010, 004	001, 024, 008	001, 006, 023	001, 030, 033	031, 037, 011	031, 015, 033	027
4	034, 015, 006	001, 034, 010	000, 010, 033	001, 044, 047	041, 050, 014	045, 022, 045	036
5	042, 018, 007	002, 044, 014	000, 012, 041	003, 052, 054	051, 061, 019	055, 029, 056	046
6	058, 027, 011	003, 062, 020	001, 018, 057	003, 069, 073	069, 077, 026	072, 039, 071	064
7	076, 037, 016	005, 079, 028	001, 025, 074	005, 083, 087	086, 091, 036	086, 052, 087	082
8	090, 046, 020	007, 092, 036	000, 031, 089	007, 092, 096	093, 096, 042	094, 061, 094	094
9	093, 052, 023	007, 095, 042	001, 033, 092	007, 096, 098	097, 097, 048	095, 068, 096	096
10	098, 058, 026	009, 099, 046	001, 037, 095	008, 097, 100	099, 098, 050	097, 071, 098	099
11	100, 060, 028	010, 100, 047	000, 041, 100	011, 098, 100	100, 098, 050	099, 072, 099	100

Figure 4. CMY densities for colour tints produced on a HP PaintJet printer

As was stated earlier, colours in ILWIS are also expressed in terms of CMY. The relationship between the ILWIS scale (0 to 1000) for these colours and the printed tint scale (0 to 11) was investigated. The correspondence is the same for each of CMY. It is given in Figure 5.

Tint nr.	ILWIS scale
0	000 - 045
1	046 - 136
2	137 - 227
3	228 - 318
4	319 - 409
5	410 - 500
6	501 - 590
7	591- 681
8	682 - 772
9	773 - 863
10	864 - 954
11	955 - 1000

Figure 5. Relationship of ILWIS intensity scale to HP PaintJet printer tints

These preliminary investigations prepared the way for the production of colour charts, for use for screen display and for printed output. The aim was that these charts should contain clearly differentiable colours, presented in colour scales of constant hue, with changes in lightness value and saturation. Some hues have very few possible variations when printed, because of the fixed number of printed tints. For this reason, and to maintain distinct differences among hues, the number of hues used was fixed at 24 only. The chart finally produced is arranged in pages, each page displaying a pair of complementary hues. Each page contains up to 100 different colours in a 10x10 block of colour squares. Each page fits conveniently on a sheet of A4 printer paper, and also on the display screen.

Hue code	ILWIS hue sat. int.	ILWIS C M Y	measured C M Y
r	000, 720, 520	000, 720, 720	006, 092, 095
rry	039, 649, 580	000, 540, 720	004, 072, 092
ry	083, 624, 640	000, 360, 720	002, 055, 090
ryy	128, 649, 700	000, 180, 720	001, 042, 089
y	167, 720, 760	000, 000, 720	001, 030, 088
yyg	205, 649, 700	180, 000, 720	017, 034, 089
yg	250, 624, 640	360, 000, 720	040, 040, 090
ygg	295, 649, 580	540, 000, 720	066, 048, 091
g	333, 720, 520	720, 000, 720	095, 062, 095
ggc	372, 649, 580	720, 000, 540	093, 054, 074
gc	417, 624, 640	720, 000, 360	091, 050, 054
gcc	461, 649, 700	720, 000, 180	090, 047, 034
c	500, 720, 760	720, 000, 000	089, 045, 021
ccb	539, 649, 700	720, 180, 000	090, 054, 023
cb	583, 624, 640	720, 360, 000	091, 067, 027
cbb	628, 649, 580	720, 540, 000	094, 083, 033
b	667, 720, 520	720, 720, 000	095, 096, 042
bbm	705, 649, 580	540, 720, 000	069, 094, 038
bm	750, 624, 640	360, 720, 000	044, 091, 034
bmm	795, 649, 700	180, 720, 000	023, 089, 032
m	833, 720, 760	000, 720, 000	004, 088, 031
mmr	872, 649, 700	000, 720, 180	005, 088, 043
mr	917, 624, 640	000, 720, 360	003, 090, 059
mrr	961, 649, 580	000, 720, 540	004, 091, 075

Figure 6. Comparison of ILWIS specifications and measured CMY percentage tints for HP PaintJet printer output, for 24 hues at rather high saturation

Because the darker tints are visually close to each other, the tint numbers 9 and 10 were not used, except where sometimes necessary in combination with tint 11, to maintain constant hues. The chart was based on ILWIS scale values 0, 90, 180, 270, 360, 450, 540, 630, 720, 810, 900, 990, i.e. one for each printed tint. A simple letter coding system was devised for the 24 hues. Figure 6 depicts the situation for all hues which contain both at least one number 8 tint and at least one zero tint in CMY. The table gives the ILWIS values for hue, saturation, intensity and for CMY, and the measured values of CMY on the printed output.

In the chart, the hue pairs red-cyan (r-c), yellow-blue (y-b) and green-magenta (g-m) contain 45 variations in lightness value and saturation for each hue. For the intermediate hues, e.g. ry, yg, there are 20 variations. For the remaining 12 hues there are only 8 variations each. Figure 7 shows the ILWIS values of CMY for chart page g-m, Figure 8 shows them for page ggc-mmr and Figure 9 for page gc-mr. Similar patterns are repeated for all other hues.

It is obvious that the gaps in the chart could be filled by ILWIS colours. For example, in page gc-mr, ILWIS colour C270, M000, Y135 fits midway between colour C180, M000, Y090 and colour C360, M000, Y180. This works well on the display screen, but when printed the hue of the intermediate colour is incorrect. None of the three colours contains magenta. The first colour consists of tint 2 of cyan and tint 1 of yellow, the intermediate colour consists of tint 3 of cyan and tint 1 of yellow, and the third colour consists of tint 4 of cyan and tint 2 of yellow. The intermediate colour therefore contains too little yellow and does not have the same hue as the other two.

On the display screen, all the selected variations within a single ILWIS hue do indeed appear to have the same hue. When printed, there are only small, acceptable variations in hue. These chart colours can therefore be used with confidence in GIS display design for both screen and printer output.

Further discussion on the characteristics and use of these colour charts will be illustrated with reference to hue gc. This has ILWIS hue 417. Figure 10 depicts the ILWIS values for saturation and intensity for all the chart colours with this hue, and for the diagonal grey scale.

white | green (g)

C 000 M 000 Y 000	C 090 M 000 Y 090	C 180 M 000 Y 180	C 270 M 000 Y 270	C 360 M 000 Y 360	C 450 M 000 Y 450	C 540 M 000 Y 540	C 630 M 000 Y 630	C 720 M 000 Y 720	C 990 M 000 Y 990
C 000 M 090 Y 000	C 090 M 090 Y 090	C 180 M 090 Y 180	C 270 M 090 Y 270	C 360 M 090 Y 360	C 450 M 090 Y 450	C 540 M 090 Y 540	C 630 M 090 Y 630	C 720 M 090 Y 720	C 990 M 090 Y 990
C 000 M 180 Y 000	C 090 M 180 Y 090	C 180 M 180 Y 180	C 270 M 180 Y 270	C 360 M 180 Y 360	C 450 M 180 Y 450	C 540 M 180 Y 540	C 630 M 180 Y 630	C 720 M 180 Y 720	C 990 M 180 Y 990
C 000 M 270 Y 000	C 090 M 270 Y 090	C 180 M 270 Y 180	C 270 M 270 Y 270	C 360 M 270 Y 360	C 450 M 270 Y 450	C 540 M 270 Y 540	C 630 M 270 Y 630	C 720 M 270 Y 720	C 990 M 270 Y 990
C 000 M 360 Y 000	C 090 M 360 Y 090	C 180 M 360 Y 180	C 270 M 360 Y 270	C 360 M 360 Y 360	C 450 M 360 Y 450	C 540 M 360 Y 540	C 630 M 360 Y 630	C 720 M 360 Y 720	C 990 M 360 Y 990
C 000 M 450 Y 000	C 090 M 450 Y 090	C 180 M 450 Y 180	C 270 M 450 Y 270	C 360 M 450 Y 360	C 450 M 450 Y 450	C 540 M 450 Y 540	C 630 M 450 Y 630	C 720 M 450 Y 720	C 990 M 450 Y 990
C 000 M 540 Y 000	C 090 M 540 Y 090	C 180 M 540 Y 180	C 270 M 540 Y 270	C 360 M 540 Y 360	C 450 M 540 Y 450	C 540 M 540 Y 540	C 630 M 540 Y 630	C 720 M 540 Y 720	C 990 M 540 Y 990
C 000 M 630 Y 000	C 090 M 630 Y 090	C 180 M 630 Y 180	C 270 M 630 Y 270	C 360 M 630 Y 360	C 450 M 630 Y 450	C 540 M 630 Y 540	C 630 M 630 Y 630	C 720 M 630 Y 720	C 990 M 630 Y 990
C 000 M 720 Y 000	C 090 M 720 Y 090	C 180 M 720 Y 180	C 270 M 720 Y 270	C 360 M 720 Y 360	C 450 M 720 Y 450	C 540 M 720 Y 540	C 630 M 720 Y 630	C 720 M 720 Y 720	C 990 M 720 Y 990
C 000 M 990 Y 000	C 090 M 990 Y 090	C 180 M 990 Y 180	C 270 M 990 Y 270	C 360 M 990 Y 360	C 450 M 990 Y 450	C 540 M 990 Y 540	C 630 M 990 Y 630	C 720 M 990 Y 720	C 990 M 990 Y 990

magenta (m) | black

Figure 7. ILWIS values of CMY for colour chart page g-m

white | ggc

C 000 M 000 Y 000				C 360 M 000 Y 270				C 720 M 000 Y 540	
	C 090 M 090 Y 090				C 450 M 090 Y 360				C 990 M 090 Y 765
		C 180 M 180 Y 180				C 540 M 180 Y 450			
			C 270 M 270 Y 270				C 630 M 270 Y 540		
C 000 M 360 Y 090				C 360 M 360 Y 360				C 720 M 360 Y 630	
	C 090 M 450 Y 180				C 450 M 450 Y 450				C 990 M 450 Y 855
		C 180 M 540 Y 270				C 540 M 540 Y 540			
			C 270 M 630 Y 360				C 630 M 630 Y 630		
C 000 M 720 Y 180				C 360 M 720 Y 450				C 720 M 720 Y 720	
	C 090 M 990 Y 315				C 450 M 990 Y 585				C 990 M 990 Y 990

mmr | black

Figure 8. ILWIS values of CMY for colour chart page ggc-mmr

white gc

C 000 M 000 Y 000		C 180 M 000 Y 090		C 360 M 000 Y 180		C 540 M 000 Y 270		C 720 M 000 Y 360	
	C 090 M 090 Y 090		C 270 M 090 Y 180		C 450 M 090 Y 270		C 630 M 090 Y 360		C 990 M 090 Y 540
C 000 M 180 Y 090		C 180 M 180 Y 180		C 360 M 180 Y 270		C 540 M 180 Y 360		C 720 M 180 Y 450	
	C 090 M 270 Y 180		C 270 M 270 Y 270		C 450 M 270 Y 360		C 630 M 270 Y 450		C 990 M 270 Y 630
C 000 M 360 Y 180		C 180 M 360 Y 270		C 360 M 360 Y 360		C 540 M 360 Y 450		C 720 M 360 Y 540	
	C 090 M 450 Y 270		C 270 M 450 Y 360		C 450 M 450 Y 450		C 630 M 450 Y 540		C 990 M 450 Y 720
C 000 M 540 Y 270		C 180 M 540 Y 360		C 360 M 540 Y 450		C 540 M 540 Y 540		C 720 M 540 Y 630	
	C 090 M 630 Y 360		C 270 M 630 Y 450		C 450 M 630 Y 540		C 630 M 630 Y 630		C 990 M 630 Y 810
C 000 M 720 Y 360		C 180 M 720 Y 450		C 360 M 720 Y 540		C 540 M 720 Y 630		C 720 M 720 Y 720	
	C 090 M 990 Y 540		C 270 M 990 Y 630		C 450 M 990 Y 720		C 630 M 990 Y 810		C 990 M 990 Y 990

mr black

Figure 9. ILWIS values of CMY for colour chart page gc-mr

white gc

s. 000 L 1000		s. 156 L 910		s. 312 L 820		s. 468 L 730		s. 624 L 640	
	s. 000 L 910		s. 156 L 820		s. 312 L 730		s. 468 L 640		s. 779 L 460
		s. 000 L 820		s. 156 L 730		s. 312 L 640		s. 468 L 550	
			s. 000 L 730		s. 156 L 640		s. 312 L 550		s. 624 L 370
				s. 000 L 640		s. 156 L 550		s. 312 L 460	
					s. 000 L 550		s. 156 L 460		s. 468 L 280
						s. 000 L 460		s. 156 L 370	
							s. 000 L 370		s. 312 L 190
								s. 000 L 280	
									s. 000 L 010

black

Figure 10. ILWIS values of saturation (s.) and intensity (i.) for chart colour gc

white gc

C 000 M 000 Y 000		C 014 M 006 Y 009		C 039 M 016 Y 023		C 064 M 030 Y 038		C 091 M 050 Y 054	
	C 007 M 007 Y 008		C 029 M 016 Y 019		C 052 M 028 Y 037		C 082 M 046 Y 053		C 101 M 068 Y 077
		C 014 M 015 Y 014		C 042 M 027 Y 033		C 067 M 039 Y 048		C 094 M 057 Y 064	
			C 026 M 026 Y 026		C 048 M 035 Y 041		C 083 M 054 Y 059		C 101 M 075 Y 087
				C 037 M 037 Y 037		C 068 M 051 Y 053		C 095 M 067 Y 075	
					C 046 M 046 Y 045		C 085 M 065 Y 071		C 101 M 081 Y 095
						C 062 M 062 Y 062		C 095 M 078 Y 087	
							C 078 M 079 Y 079		C 101 M 090 Y 098
								C 092 M 093 Y 093	
									C 099 M 101 Y 102

black

Figure 11. Densitometer measurements of CMY percentage tints on HP PaintJet printer output of chart colour gc

white gc

d 0.00 s1 0 s2 0.00		d 0.04 s1 8 s2 7.00		d 0.11 s1 23 s2 20.42		d 0.21 s1 34 s2 30.78		d 0.44 s1 41 s2 39.15	
	d 0.04 s1 1 s2 1.00		d 0.08 s1 13 s2 11.79		d 0.16 s1 24 s2 21.00		d 0.34 s1 36 s2 33.06		d 0.69 s1 33 s2 29.55
		d 0.06 s1 1 s2 1.00		d 0.14 s1 15 s2 13.08		d 0.25 s1 28 s2 24.76		d 0.50 s1 37 s2 34.04	
			d 0.11 s1 0 s2 0.00		d 0.19 s1 13 s2 11.27		d 0.38 s1 29 s2 26.85		d 0.76 s1 26 s2 22.54
				d 0.17 s1 0 s2 0.00		d 0.30 s1 17 s2 16.09		d 0.56 s1 28 s2 24.98	
					d 0.22 s1 1 s2 1.00		d 0.45 s1 20 s2 17.78		d 0.84 s1 20 s2 17.78
						d 0.35 s1 0 s2 0.00		d 0.68 s1 17 s2 14.73	
							d 0.56 s1 1 s2 1.00		d 1.05 s1 11 s2 9.85
								d 0.86 s1 1 s2 1.00	
									d 1.60 s1 3 s2 2.65

black

Figure 12. Densitometer measurements of neutral density, and two measurements of saturation, on HP PaintJet printer

Figure 11 shows the result of measuring the percentage tints of CMY on the printed output, using the densitometer. Figure 12 shows the measured density (d) of each colour, using the neutral (black) filter. This figure also shows two values for saturation of the printed colours, calculated from the measured percentage tints of CMY by two different methods.

$$s1 = max.\ tint - min.\ tint$$

$$s2 = \sqrt{C^2 + M^2 + Y^2 - CM - CY - MY}$$

In general, both on the display screen and on the printed paper, the saturation of a chart colour increases with increasing distance from the diagonal grey scale. One would expect that colours along any line parallel to the grey scale would have the same saturation, becoming darker in the direction of black. Reference to Figure 10 shows that on the display screen this does indeed occur, with the exception of the colours in the right-hand column, which have higher saturation. On the printed chart (Figure 12), saturation tends to be somewhat higher in the middle of such scales than at the ends. Colour scales like this are in many ways analogous to the isochrome series of the Ostwald colour system[8].

Colour scales which follow the direction from white to the full colour (horizontally in the case of hue gc) correspond to the Ostwald isotone series. In this direction, the colours become darker and saturation increases (but note that the colours of the right-hand column of the printed chart actually have decreased saturation). Colour scales which follow the direction from black to the full colour (vertically upward in the case of hue gc) correspond to the Ostwald isotint series. In this direction, the colours become lighter and saturation increases.

On the display screen (Figure 10), colour scales in the direction perpendicular to the diagonal grey scale show increasing saturation and constant intensity, with the exception of the colours of the right-hand column, which are darker. On the printed chart (Figure 12), these colour scales show increasing saturation and decreasing lightness value, i.e. higher densities.

Practical limitations on the use of saturation to depict quality information

We have just shown that it is not possible to produce a systematic set of PaintJet printed colour scales in which hue and lightness value are kept constant, while saturation varies. Reference to Figure 12 reveals very few chart colours of hue gc with closely similar density but different saturation. Consequently we have to accept that lightness value will vary along with saturation in the printed scales. If saturation is used to indicate information quality, it actually may be desirable visually to reinforce increasing saturation, indicating higher quality, with increasing darkness. Increasing darkness, however, could be associated with ordered or relative quantitative attribute information, instead of quality information. For this reason we suggest here to use saturation as the main variable to represent quality. Darkness changes should be kept moderate, with only a subordinate function.

An additional limitation on the use of saturation scales, in the case when a GIS display must contain many such scales, is that colours of low saturation may be difficult to distinguish from each other. This implies avoidance of colours close to the diagonal grey scale in the colour chart. A similar problem arises with the use of isotint scales. The differences in saturation and lightness value between adjacent colours of such scales are rather small. Furthermore, the more saturated colours are lighter than the less saturated colours. In this case, then, changes in saturation and lightness value visually conflict, and this is likely to confuse users who expect "dark" to mean "more".[6]

If we wish to choose a four-step scale of hue gc for printed output, with clearly perceptible differences in saturation but only moderate differences in lightness value, we find ourselves limited to one only, perpendicular to the grey diagonal (Figure 13). Note that if we have to avoid rather desaturated colours, as previously explained, then colour 1 should be omitted, and a four-step scale is then not possible.

Colour	ILWIS C M Y	ILWIS sat. int.	Paper C M Y	Paper sat (s2) density
1	450, 270, 360	156, 640	48, 35, 41	11.27 0.19
2	540, 180, 360	312, 640	67, 39, 48	24.76 0.25
3	630, 090, 360	468, 640	82, 46, 53	33.06 0.34
4	720, 000, 360	624, 640	91, 50, 54	39.15 0.44

Figure 13. A four-step saturation scale chosen from chart colour gc

A similar situation exists for the hues ry, yg, cb, bm and mr. The hues c, m, y, r, g and b offer more and longer scales, although in each case only about five four-step and three-step scales approach the ideal. The remaining hues each offer one reasonable two-step scale but no four-step or three-step scales. Note that for the hues containing a high proportion of yellow it is better to use an isotone scale rather than a diagonal scale, because in this case the lightness value differences are less along isotone scales.

We can therefore conclude our argument by stating that if we want to represent three quality classes of categoric area information in a GIS display, suitable for screen display and for output on a HP PaintJet printer, and we wish to use the colour visual variable saturation as the main variable, then we are limited to 12 information categories. For these we can use the hues cyan, magenta, yellow, red, green and blue and the hues midway between these in the colour circle. A similar situation is probable for other combinations of GIS software and colour printer. Note that the situation improves if we can go to raster film plotter output, since we are then not limited to a small set of percentage tints. To avoid possible confusion, however, only one saturation scale per hue should be used. Also, there should be sufficient differences between hues at the lowest saturation used. It seems a reasonable assumption that for this kind of output the maximum number of usable hues, and therefore the maximum number of information categories (each with three quality classes) for simultaneous display, is not more than about 24.

Conclusion

Cartographers need not be convinced anymore of the usefulness and effectiveness of colour to represent qualitative, ordered and relative quantitative geographic information in maps. For the specific case of the cartographic representation of categoric area information generated by a GIS, in this paper it is argued that the visual variables of colour (hue, lightness value and saturation) may also be used very well to portray information quality next to the attribute information itself in the same display. In particular, it is recommended to use saturation - often disregarded in cartographic symbol design principles - to represent the aspect of information quality. Practical guidelines are provided for its application on both paper and display screen, for one particular combination of GIS and output device, though the method can be used for any combination. It is hoped that the results of our investigations may be incorporated in the ILWIS "Uncertainty Subsystem", which is in development in the ITC Cartography Division.

Although the guidelines presented are very practical and concrete, it is realized that the initial assumptions made are still theoretical. That is to say, more research experiments are still needed on the perception of the visual variables of colour, applied in a map, alone or in combination and on different output devices, for the representation of information quality, comparable to the experiments carried out by Schweizer & Goodchild[6].

An important drawback of this paper in its written form is of course that it was not possible to include coloured illustrations. However, the intention is to publish a Dutch version, with coloured illustrations, in Kartografisch Tijdschrift 1993.XIX.4.

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From GIS to final print-ready films

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Abstract

To produce maps with GIS data is one of the purposes of geographic information systems and often considered to be without any problems today. To verify this statement we had an opportunity to carry out a practical test. This contribution reports on the work flow of such a mapping project aiming at colour separation films ready for printing and experiences gained along this project.

System and programs

The Institute of Cartography of the Swiss Federal Institute of Technology in Zurich (ETHZ) has at its disposal a hardware and software configuration which was installed during the year 1989. This system allows for a simultaneous handling of raster and vector data. It consists of six workstations; three additional PC-stations are planned to be added. Two workstations are provided each with a large digitizer. A pen-plotter is used for simple control plots, a thermo printer for coloured hard copies. The high resolution input/output system consists of an Optronics laser scanner/raster plotter.

We make use of some thirty different software items, e.g. packages for handling raster and vector data for electronic screening of digital map images including masking possibilities and GIS data; the necessary plot moduls are contained as well.

Description of the problem

For several years data about the ecological situation in the Grisons have been surveyed and compiled by the Department of Planning of ETHZ in an ARC/INFO-system. There was now a need to publish maps in colour to show conflicts and syntheses at scales 1:25'000 to 1:100'000. Different base maps at larger scales had been used for local investigation. But they were not appropriate for regional overviews. For publishing maps with this basic information in the desired scale range, laborious generalization steps were therefore necessary. For this reason the Department of Planning asked the Institute of Cartography for assistance in the generalization process, that consists in adjusting the vector data of the GIS-system to the geometry of the rasterized base map. We were asked also to produce colour separated print-ready films for the publication of the results of these investigations in maps with high graphic quality.

Datatransfer

For the exchange of the data between the ARC/INFO-system and the CIS-system the common Auto CAD ASCII Drawing Exchange File-Format (DXF) was chosen. This exchange format is in both systems implemented as a standard. The original data were already separated in the ARC/INFO-system in different data layers and could be written as single DXF-files on floppy-discs under control by the DOS-system. Nine files were created for the land use map ("Landnutzungsstruktur") and eleven for the map "Vorrang- und Ausgleichsflächen". In addition to the transfer via discs an exchange with magnetic tape, video tape or on an Ethernet is available too. With the Intergraph program routine (DTU) the DOS-datafile could be read and translated into datasets that are managable under UNIX. Furthermore a translator changed the UNIX-DXF-files in graphic files, so called DGN-Files, that can be handled by the microstation program. Some limitations were inherent to this transfer. The DXF-format unfortunately does support neither the microstation element types ellipse, partial ellipse, curve, bispline, complex string nor the element types shape and complex shape. ASCII tables establish a correspondence between the DXF- and the microstation format only for datalayers, cellnames, textfonts and line styles.

Forming closed areas (complex shapes)

As explained above a transfer of closed areas represented by Intergraph through the elements shapes and complex shapes when using the DXF exchange format is not practicable. However, closed areas are a prerequisite for filling in pattern and / or colours. Microstation does not provide for an automatic complex-shaping. Considering to the great number of closed areas to build, interactive tagging of the single lines on the display was out of question. The microstation-GIS-Environment software package (MGE), however, allows for a program supported realisation of this working step in four phases.

1. phase cleaning the dataset (line cleaner software)
   This utility fixes or flags invalid line work. It corrects any undershoots, overshoots, intersections and duplicated line segments. Depending on the option choosen the errors are either only flagged or directly corrected.
   After processing the data through this line cleaner utility a cleaned and tested dataset is available, that allows now to build correctly closed areas.

2. phase creating features from graphic elements (feature maker software)
   In this step attributed features were created from graphic elements. To the elements a feature linkage defined in advance is attached.
   In this step the graphic elements are transformed into predefined attributed features.

3. phase placing of centroids (centroid placing software)
The centroid placer utility automatically places a centroid within the outline of each area feature.

4. phase area complexing (complexing software)
The complexer utility supports the conversion of linework and centroids into complex shapes. Thereby all line elements around a centroid are connected into a complex shape. Due to the very detailed structure the time needed for forming approx. 3000 areas was indeed about 3 working days. Nevertheless this program supported process was much faster, more userfriendly and comfortable in comparison to the laborious and painful interactive procedure.

Preparation of the base map

For the publication, the so-called total image of a Swiss topographic map at the scale 1:100'000 was chosen as base map. The Swiss Federal Office of Topography delivered positive films of the two adjoining map sheets (see figure 1).

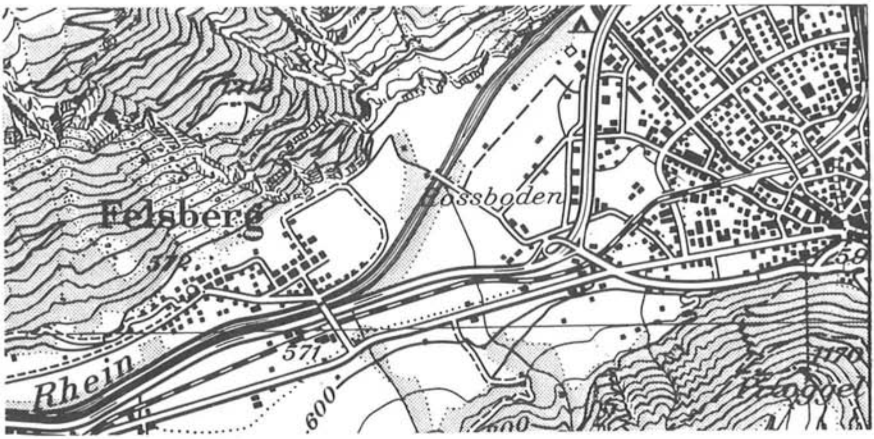

Figure 1: Section from the total image of the official topographic map 1:100 000 (enlarged to 1:50 000) that was used as base image.

A scan of the map section was executed and used as final publication elements and as background image on the display of the workstation in combination with the thematic information in vector format. To realise better contrast conditions for an optimal scan, the positive film was copied on white opaque material. After scanning the graphic information of the base map it is available in digital form as a binary raster image.
At this stage the raster image does not yet match the vector data on the workstation display. Correspondence between the two images is not yet established.
Therefore a transformation of the raster image to the vector base is necessary. A utility called

warping is incorporated in the Intergraph I/RASB software for compressing, stretching and rotating the binary pixel image until an optimal register with the vector data is achieved. Both data sets include a graticule. Therefore intersections of the graticule lines were chosen as control points. For this transformation a linear interpolation function was used. Up to 100 control points can be handled with the I/RASB warping utility. As interpolation functions 1st to 5th order polynoms are allowed. After the warping process the raster and vector data are in register and can be displayed together on the workstation.

Cartographic treatment

Now follows an extensive and time consuming interactive working step in the whole map production process, which, however, is essential when graphically well designed and readable maps are wanted. Efficiently and userfriendly editing functions largely influence the amount of work (see figure 2).

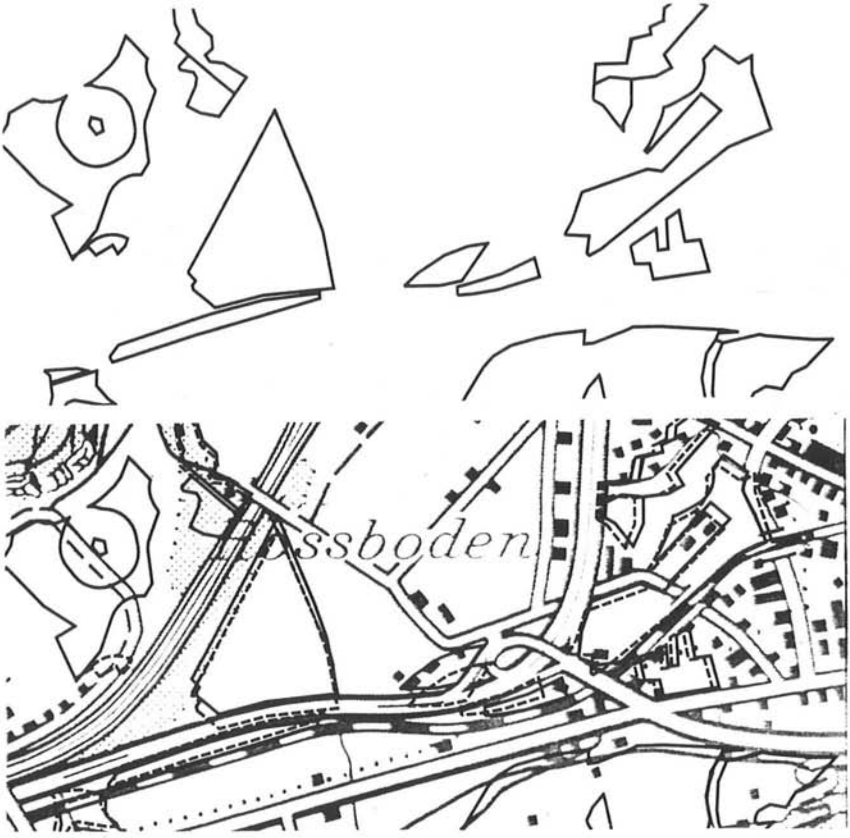

Figure 2: Above a section of the raw data, below with generalized data and raw data (broken lines) combined with the base map image.

The following operations were necessary:

1. **Positional modification of the vector data to fit it to the geometry of the base map**
As the thematic data was compiled by hand on large scale maps, it did not fit to the enlarged section of the topographic map 1:100 000 to be used for publication. The use of an enlarged section of a topographic map as base is recommended. Such a base map does not include too much detail, what will influence the readability of the map in a positive sense. However, as the total scale factor between working and publication scale is four or more, a generalization is absolutely necessary (figure 3).

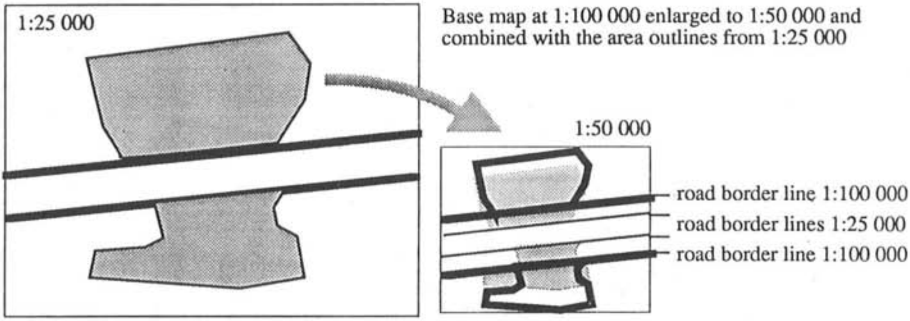

Figure 3: The different road widths of the maps at 1:25 000 and 1:100 000 (published in 1:50000) ask for generalization.

In this project the map editor modified interactively the geometry of the vector data directly on the display. Only the most obvious deviations were treated, especially situations where areas crossed motorways, rivers, railways etc. or did not fit exactly to the line geometry of the base map. The microstation software allows the following editing functions.

1. Modification of the area outlines point by point (figure 4)

2. Moving the whole area, which is especially suited for small isolated areas. (figure 5).

3. Deleting vertices and inserting new ones (figure 6).

4. Shifting a number of vertices (figure 7).

However, such changes of the area outlines are allowed only within a given tolerance and under the condition that the caracteristic geometry of the the different areas is retained.

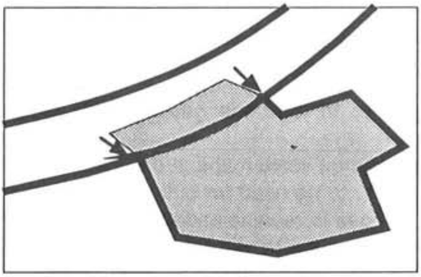

Figure 4: Interactive modification of the area point for point

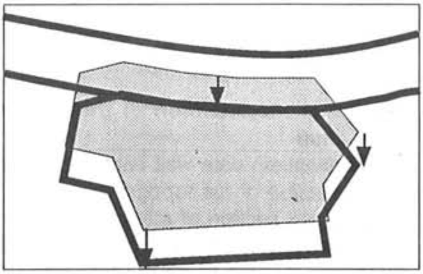

Figure 5: Shifting the total area by a move command. Only possible in cases, where no conflicts arise with neighbouring areas

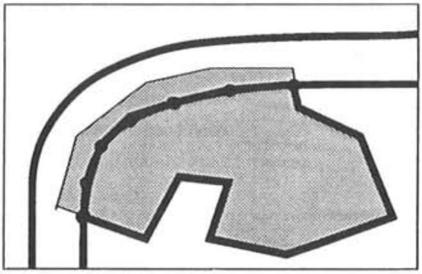

Figure 6: Modification of the area outline by deleting vertices and inserting new ones

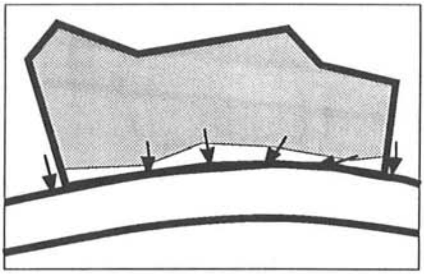

Figure 7: Area modification by shifting a number of vertices

In most cases a combination of these utilities were used. If the modification results in totally new line geometry, the complex shapes are better completely dropped. New lines are added and interactively joined to a complex shape before deleting the wrong lines. This whole procedure is very complicated and moreover cumbersome in comparison to the ARC/INFO-system, that includes a utility which allows to delete wrong line segments and to digitize correct ones without loosing the area definition.

2. Elimination of small areas

Area intersection calculations that we executed in the ARC/INFO-system produced very small areas, which would hardly have been visible at publication scale. These small areas can be detected and eliminated by fixing a threshold for a minimal area already in the ARC/INFO-system. A transfer of small areas to the Intergraph-system would then have been avoided. In this case, however, a large amount of too small areas had to be interactively deleted or enlarged where important.

3. Placement of line end symbol

In one of the maps produced arrows are added to some ends of lines. This was easy to realize with the powerful line terminator function. The placement of correctly orientated symbols at the line ends can be executed with this utility.

4. Construction of tinted bands

In one of the maps some lines are presented by a tinted band in addition to the solid line. Complex shapes are required for establishing these bands. The closed areas were generated by copying the solid line with a defined distance and adding to a complex shape. One working day was needed to build about 100 areas.

5. Legends and placement of text

Separate design files were used for the construction of legends and the placement of text. Merging with the corresponding datafiles is then easy to realise at a later stage. As every map contained a north and a south sheet the legend had to be build up only once per each map. The second was then derived by copying, rotating and editing the appropriate texts.

6. Treatment of the islands problem

In the map publishing process complex shapes with islands are not taken care of. Therefore an alteration of the data was necessary in such a way that the island areas reside on a different data level as do the associated areas. It is then possible to generate separate raster files in further steps (figure 8). Masking can be made by logical raster operations or by a suitable specification in the specification table. For more information see next chapter.

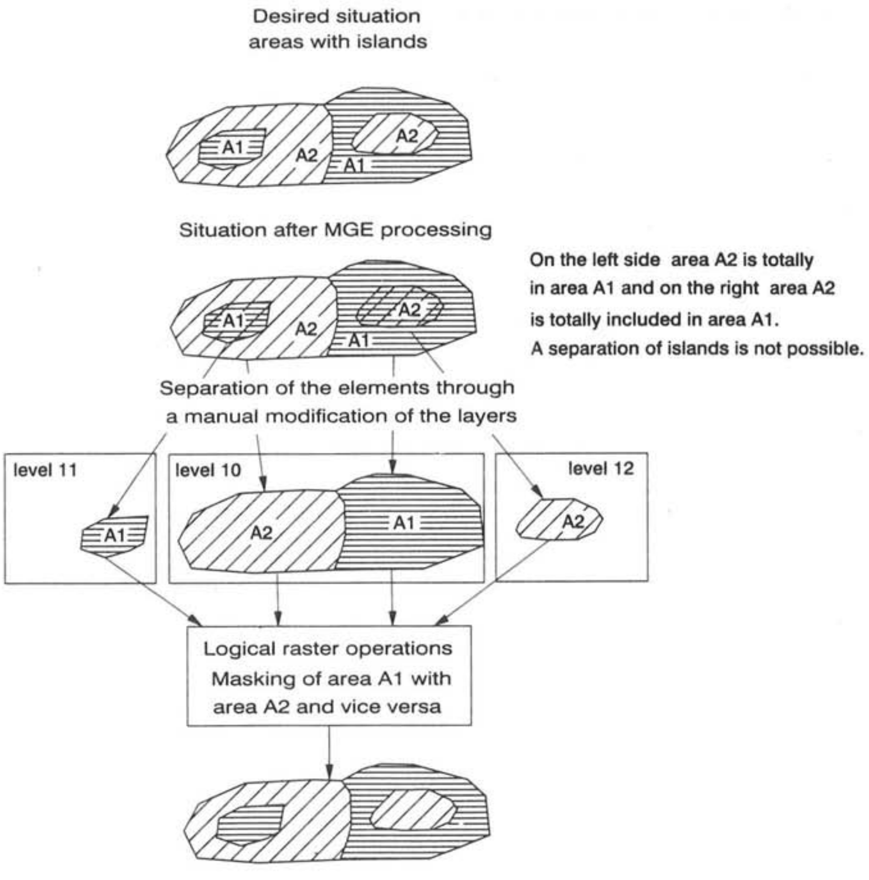

Figure 8: A separation of island areas and later masking is possible only, when the islands are switched on different levels.

Map Publishing

The map publishing process may be compared with the traditional process of assembling all originals on a set of colour separation films. Some additional work steps are necessary, however, for the digital procedure.

Rasterization of the vector data

First of all the vector data has to be transformed to raster data. Line style, scale, image orientation and raster resolution are defined in a command file (figure 9). Then the file is queued to the raster driver, the vector data is transformed in raster data.

```
# command file for generating the separate rle files from the design file
#
# first create master .i with a fence to be used for all later .i's.
#
# set pen table and design file and all other global qualifiers

 iplot mod -queue=mappub2032 /usr/tmp/master.i
 iplot mod -rotation=0 /usr/tmp/master.i
 iplot mod -mirror  /usr/tmp/master.i
 iplot mod -pen_table=/usr2/cb/gfeller/brht.pen  /usr/tmp/master.i
 iplot mod -color_table=/usr/ip32/ip/iplot/bw.ctb /usr/tmp/master.i
 iplot mod -fontlib=/usr/ip32/mstation/bsfontlib /usr/tmp/master.i
 iplot mod -nolev=[1-63,60] /usr/tmp/master.i
 iplot mod -nodisplay=text_nodes /usr/tmp/master.i
 iplot mod -design=/usr2/cb/gfeller/lepgrzout.dgn  /usr/tmp/master.i
 iplot mod -nofast=font /usr/tmp/master.i

# insert appropiate design file, pen table as required

 cp /usr/tmp/master.i /usr/tmp/pass.i
 iplot mod -level=[55] /usr/tmp/pass.i
 iplot generate /usr/tmp/pass.i
 iplot submit /usr/tmp/pass.i

 cp /usr/tmp/master.i /usr/tmp/rafein.i
 iplot mod -level=[5] /usr/tmp/rafein.i
 iplot generate /usr/tmp/rafein.i
 iplot submit /usr/tmp/rafein.i

 cp /usr/tmp/master.i /usr/tmp/ragrob.i
 iplot mod -level=[6] /usr/tmp/ragrob.i
 iplot generate /usr/tmp/ragrob.i
 iplot submit /usr/tmp/ragrob.i

 cp /usr/tmp/master.i /usr/tmp/black.i
 iplot mod -level=[50-54] /usr/tmp/black.i
 iplot generate /usr/tmp/black.i
 iplot submit /usr/tmp/black.i
```

Figure 9: A typical section of a command file that allows for the generation of separate raster files from vector data

```
"Pentable for project brht"
IF (LEVEL .IN. 50,54) THEN
  THICKNESS = 0.015
ENDIF
IF (LEVEL .IN. 51,52) THEN
  THICKNESS = 0.0125
ENDIF
IF (LEVEL .IN. 53) THEN
  THICKNESS = 0.020
ENDIF
IF (LEVEL .IN. 55) THEN
  THICKNESS= 0.008
ENDIF
IF (LEVEL .IN. 31,32) THEN
  THICKNESS= 0.0125
ENDIF
IF (LEVEL .IN. 5,6) THEN
  THICKNESS= 0.010
ENDIF
IF (LEVEL .IN. 11-15,31,32,56) THEN
  AREA_FILL= .TRUE.
  ELSE
  IGNORE_ELEMENT= .TRUE.
ENDIF
```

Figure 10: Example of a pen table for controlling the symbolization of the linear elements

Extraction of the exact map section of the base map image

As the north sheet and south sheet of the topographical map 1:100 000 were scanned together, an extraction of the exact sections from the base map has to be made for processing the single sheet. These sections could be produced with the helpful extract function of the I/RASB-software. Because the map publishing process demands, that all raster files have the same dimension, respectively number of rows and columns, an affine interpolation had to be accomplished with the single sections onto the pixel matrix dimension.

Logical raster operation

For handling the island problem logical raster operations had to be executed. Figure 11 shows a typical command file for this task. The lines 2 to 7 and 11 to 12 define masking processes. In line 8 and 9 a logical "and" operation is executed. It allows the addition of patterns to the corresponding areas (see figure 12).

"logical file for brht"				
flip		mask.rle	maskflp.rie	
logical_rle	lbcd.rle	la.rle	lam.rle	-m
logical_rle	lacd.rle	lb.rle	lbm.rle	-m
logical_rle	labd.rle	lc.rle	lcm.rle	-m
logical_rle	labc.rle	ld.rle	ldm.rle	-m
logical_rle	lg.rle	le.rle	le15.rle	-m
logical_rle	lg.rle	lf.rle	lf15.rle	-m
logical_rle	le15.rle	rafein.rle	lera.rle	-a
logical_rle	lf15.rle	ragrob.rle	lfra.rle	-a
logical_rle	le15.rle	lfra.rle	lfrax.rle	-m
logical_rle	lf15.rle	lera.rle	lerax.rle	-m

Figure 11: A command file for executing logical raster operations

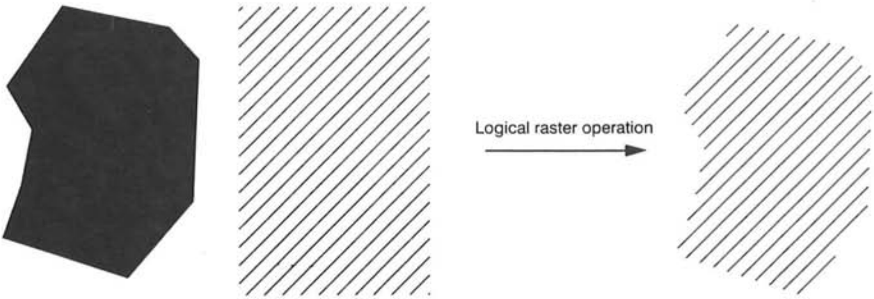

Figure 12: Example of a logical AND operation with two raster files, with command sequences according to figure 11 line 8 and 9

The photolab specification file

This file is comparable with the traditional colour specification table. The screen percentage of the printing colours for the different map elements are determined as well as the portions of display colours, the depth of masking and printing priorities etc. Figure 13 shows a typical photolab specification file.

```
screener3
"                              brht project"
"-----------------------------------------------------------------------------"
"                         print inks ------>|"cyan yell mage black
" screen numbers for slots 1 & 2 ------>|"2,0  1,0  4,0  3,0
" screen numbers for slots 3 & 4 ------>|"0,0  0,0  0,0  0,0
"-----------------------------------------------------------------------------"
```

SPEC TABLE DATA						CRL display%			OUTPUT percent of ink				
pri	depth	typ	op1	op2	RLE feature_name	R	G	B	C	Y	M	K	notes
1	0	s	1	0	pass;	4	4	4	100	100	100	100	
10	0	s	1	0	text;	4	4	4	0	0	0	100	
20	0	s	1	0	black;	4	4	4	0	0	0	100	
30	100	m	1	0	maskflp;	100	100	100	0	0	0	0	
40	0	s	1	0	brhtsued2;	80	80	80	0	0	0	40	
50	0	s	1	0	lam;	4	97	51	0	50	90	0	
60	0	s	1	0	lbm;	69	97	51	0	80	60	0	
70	0	s	1	0	lcm;	86	97	51	0	90	30	0	
80	0	s	1	0	ldm;	97	97	51	10	100	10	0	
90	0	s	1	0	lera;	38	97	95	100	0	0	0	
100	0	s	1	0	lfra;	38	97	95	100	0	0	0	

Figure 13: A typical example of a specification for a screening and masking table

The path file
After rasterization of each lithographic symbology class there exist separate raster files for each of them. The path file physically correlates the specifications for each symbology class with the corresponding raster data. In addition it contains also the names of the display files and the used pattern and screen libraries.

The photolab process
The traditional assembling of all originals and masks to colour separation films in the dark room is now replaced by an electronic rasterization. A WYSIWG-possibility on the display of the workstation replaces the proof copy. Mistakes like missing or wrong masks, uncorrect line thickness, missing areas etc. may be detected on the display and corrected in the appropriate stage in the map production process. Plotfiles for producing colour separated print ready films or display files are the result of the photolab process.

Laser raster plots

After eliminating all discrepancies the colour separated print ready films are produced from the plot files with the laser raster plotter Optronics 5040. The area and lines screened according to the specified screen percentages, screen angles and intervalls are created by the screener board. The films are of a high graphic quality and may be directly used without any retouching for producing the printing plates.

Conclusions

In conclusions of the testwork can be summarised:

1. In spite of the advanced computer-assisted techniques used a lot of data handling and editing work is still to be done from data transfer to films ready to print.

2. Thorough knowledge in computer-assisted methods of map production is needed by the operator, as well as graphic skills and experience in applying graphic rules. It is the merit of the operator when the final product is a graphically pleasant and readable map. Maps produced with modern computer technology by amateurs are often unsatisfactory, because their graphic form is conditioned by the the technical possibilities and does not care for the graphical rules. Such a dominance of techniques over graphic design must be refused in the interest of the map users.

3. From the beginning a data organisation must be envisaged that allows to eliminate time-consuming work in subsequent steps.The purposes of the data output must be clarified.in advance. It is an illusion to believe, that having detailed geometric data in a GIS-database, there is no problem to produce graphic output in the form of maps at any time.

4. The data transfer between different GIS-systems is still a problem. An exchange of the geometry is usually easy to realise. There are more problems, when the data topology and the attributes are needed as well. The different element types in different GIS-systems are in some cases very embarassing, e.g. the definition of closed areas etc. For the future data exchange on a higher level is absolutely necessary, eventually with a common standard data exchange format.

5. Careful graphic coordination of the compiled data with the base map image is essential. Scale-free data, as often postulated, in fact do not exist. Graphic data extracted from a GIS can only be used in a small restricted scale range without any generalization. For larger scale changes a generalization step is required. It must be investigated case by case, if a computer supported generalization is possible. Usually a cumbersome interactive generalization is the only way to achieve a good result, with the base map image geometry coordinated to the GIS-data. The tendency to compile huge amounts of geometric data in GIS-systems creates an increasing need for final visualization of the data in form of maps. Too often not enough consideration is given to these output problems, what may cause a considerable waste of time.

6. Especially when working with raster data, large amounts of data have to be handled, when complex graphic maps are treated in CAD-systems. This can lead to extensive reaction and display times. Otherwise a representation of vector and raster data gives no special problems in map production, but may increase the attractivity of the map, e.g. when a rasterized topographic map or a satellite scene is used as base map image.

   Similar experiences were made with other projects. The transfer of digital cadastral data from a system of a private office to the Intergraph-System e.g. could only be executed on a very low level without any transfer of data topology and attributes. These restrictions had a great impact on the further treatment of the data. An interactive re-establishment of the missing attribut was necessary. For some smoothing operations single line segments had to be rearranged. If for instance a computer assisted calculation of the road axis had to be done in cases where the borderline data were available only in an unordered form. The same is true for the houses. It is obvious that a carefully considered data compilation in the beginning influences later on the computer-assisted map production process in a positive sense. When starting off it must be clear for what purposes and how the compiled data could be treated afterwards avoiding a huge effort of interactive work. This is one of the conditions which is often not considered in detail and leads to databanks that may be useful for a number of purposes but not for graphic output in map form.

7. One might argue that all these problems had been avoided, if the topographic map would not have been chosen as base map. The alternative might consist of some – usually poor – vector elements that provide for the necessary minimal orientation background in the map. There are mainly two drawbacks in this solution. On one side the map user has no framework that is dense enough to locate the thematic information accordingly. On the other side the lack of a need for generalization may be a temptation to be satisfied with a poorer map in general. Too often GIS-output does not meet usual mapping standards. But using a raster image as a base map forces the editors to increase map quality.

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Research and production of electronic color atlas

B. Jiang, Q. Zhang (Beijing, RC)

INTRODUCTION

Colour is one of the cartographic languages, and is a significant element which constructs map formal aesthetics. A successful map always attract map readers by a wide range of reasonable pairs such as harmony, and contrast.
In the past two years, some colour atlases were produced by several Institutes respectively in China. These atlases were designed scientifically, printed wigh high quatity and accommodated the engineers who major in image reproduction or color design a "Color Dictionary" with standardized color data.
Recently, computer image processing technology has developed rapidly with the trend of replacing traditional image reproduction procedures. Computer is based on the digital form, while traditional image information products such as photoes and prints, are analogue products. Notably, analogue products are better than digital products in quality of appearance, but revises, edits before printed are based on the computer mainframe. Some companies had spent most of their time and cost on the development of color computer image edit system since midle of 1980's.
Color image original can be imported to computer by color scanner. Operator can do some on-screen processing, such as composition and color correction for color images, then produce samples with digital color proof devices, and also show the result on the screen directly, even export the separated film with imagesetter.
In china, color image processing technology can be compared with situation on abroad, especially in the domain of remote sensing application. Otherwise, there is a scarcity of color reproduction system integrated with image processing, image edit and image reproduation. The expensive system mentioned above from abroad does not fit to China situation. It is necessary to reexplore such existing instruments, Such as image processing computers, high resolu-

tion monitor and electronic scanner. The Electronic Color Atlas which introduced in this paper realized the function of "What You See Is What You Get For Color Image". This research work made a preliminary foundation for exploring image reproduction system suited for China situation.

UNDERLYING THOUGHTS OF THE SYSTEM

It can be seen on figure 1 that color original imported into system with the video monitor can ensure agreement of appearance between original and electronic image, even between the original and the relevent prints when there is a need to export in an analogue form. To do this, the reseach of the system employed a kind of method called "black box" which only investigate the input and output and not internal structure.

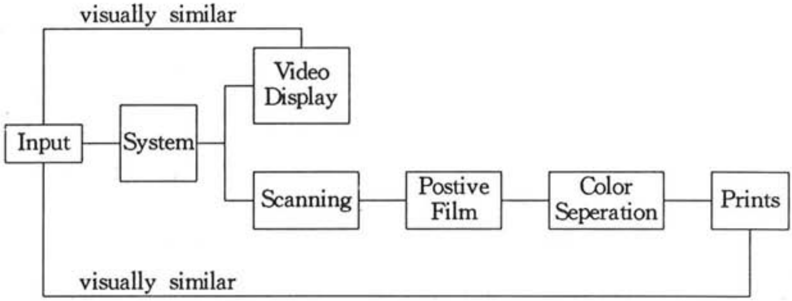

Fig. 1 The goal of system design

Limited by various conditions for some objects to be investigated, their structures and mechanism can not, or with many difficulties, be studied. These objects seem to be opaque but sealed boxes with their sophisticated structure and mysterious mechanism involved them, and it is impossible to be stuied directly outside it through opening it. Such objects are named "closed box", and then, "black box" by the originators of cybernetics.

Desktop colour reproduction system needs video display to be good colour-render. It has been formed during the screen produced. Fluorescent coating on the fluorescent screen's inner surface is a dominant factor affecting illuminian features of Kinescope, while the refinement extent of precedure as a factor can not be neglected, although kinescope structure is not a black box to computer users, but for the convenience of study, it is a black box from original input to the video display. (Fig. 2)

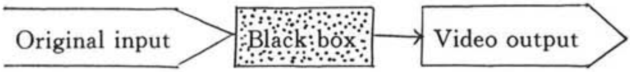

Fig. 2 Setting up black box (1)

The design ability of color image system is strengthening day and day, but the prints by scanning, color seperating, printing are generally distorted beyond recognition resulted from many aspects of reasons including scanning, watering, color-seperating, plate-making and printing. From this point, researchers can not regard this process as a black box, but a grey of even white box. Color is likely very "fragile" because of its sensitivity, e. g. its structures to the environments. When block color is stared for a long time, negative afterimage will appear, i. e. color being stared at tend to change to its complementary color resulting is reduction of color saturation. Color recognition will be also affected by the operator's mood and ages in the process of reproduction. This effect, of course is just on pyschological and physiological reproduction factors, and unstable reproduction precedure, the other hand, has more effects on colors. Inquired by the study, all stages of reproduction procedures are proceeded under strict quality control, associated quality control refer to EXPLANATION in COLOR ATLAS. and therefore, the overall procedure can be studied in a " black box" (Fig. 3)

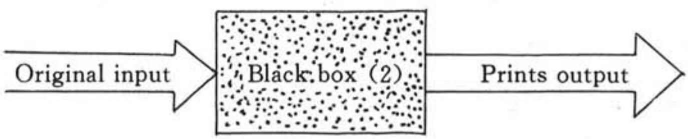

Fig. 3 Setting up black box (2)

Based on the design principles mentioned above, the look up table between the screen display, output printer's ink and standard pallet can be constructed.

SYSTEM IMPLEMENTATIONS

Environment of the system is as follow,

1. COMTAL Image Processing System
   Processor: LSI-11 Processor
   Resolution of Monitor: 512×512
   Image board: $512 \times 512 \times 25$bit
2. 330A scanned output equipment (Japanese Kimoto Co.)
3. CP-341 electronic scanner (Germany Hell Co.)
4. MS-C5.0 and dBase III

Two black boxes have been derived from the environment, then the Look-Up-Table between input and output can be set up, through investigating two black boxes and measuring input and output data. Map printing now is developing in the direction of 4-color printing, yellow, magenta, cyan and black, considering that most of the present color prints are based on 4-colors, three-color overlapping part $12 \times 12 \times 12 = 1728$ kinds of colorful block colors in COLOR ATLAS as the input to the black boxes in our study. Rich and varied colors in prints, according to color image reproduction theory, stem from the mixtures of yellow, magenta, cyan and black in different proportion. Research into the basic color degradation is benefit to reveal color degradation rules. The output from black boxes can generate a standard pallet ($16 \times 16 \times 16 = 4096$ kinds of bolck colors). See Fig. 4.

Generation and output of the standard pallet

The standard pallet is composed of red(R), green(G) and blue(B) spectrals. In order to make the standard pallet covering as the overall color blacks in the Color Atlas possible, while not too complexed. Two methods, equi-different grading and incompletely equi-different grading, have been tested. The later one, which has the grade 0, 12, 25, 38, 51, 64, 76, 89, 102, 115, 128, 153, 179, 204, 230, 255, was selected as a suitable standard palet. According to testing result, it has been divided into 16 pages for the ease of organization. Each page has $16 \times 16 = 256$ bolck colors (Fig. 5). The standard pallet outputs with two formats, one is video output and another is analogue one.

Analogue output is based on 330A Scanner, using Kodak film (Positive) with size 25.4cm$\times$25.4cm and sensitivity 100ASA, scanned pixel size is 50u. Red,

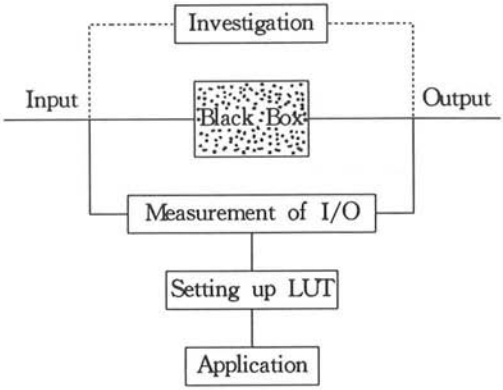

Fig. 4 flow chart of system implement

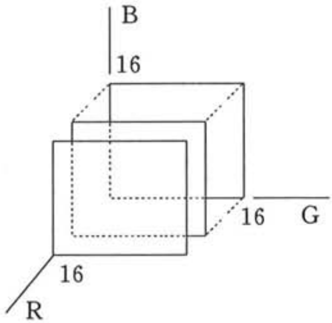

Fig. 5 Constructure of pallet

green and blue scales are added in the edge of the standard pallet for the ease of quality control, CP-341 color scanner was employed in color scanning.

Quantitative colour measurement

Qantitative color measurement must be done under the condidions of a certain standard light source. Colorimetric standard illuminants and color sources have been defined in CIE to unify the standardization for the quantitative color measurement. C light source, in this experiment, was selected as the measuring light source because it is nearer to sun light. Instruments used for color measurement is SE $-\Sigma$80. The distributions of every color blocks in color space and their corresponding spectral sensitivity curves are printed out while measuring in order to check if there are mistakes.

Measuring condition:

Color temperature: 6740K

Colorimetric coordinate: $X_0=97.298$

$Y_0=100$

$Z_0=116.137$

Standardwhite: Colorimetric coordinates: $x_0=93.77$

$y_0=95.60$

$z_0=113.76$

Measuring the screen color is different form one of prints, because prints are reflectitive matters, the measured light coming from outside. While screen itself is a light source. To the scveen, outside light has hardly any effects on its colormetric value, and even can be neglected (Tab. 1)

Measuring conditions:

Light source: according to screen itself

Standard black: the original color of the screen itself

Table 1, Effective of external light to chromaticity of screen colors

	0101	1010	0110	1101	1011	1111	0000
1	286 347	288 344	288 346	286 347	281 349	287 346	286 347
2	289 334	290 333	291 332	289 335	287 336	289 335	289 332
3	294 322	291 325	292 325	293 323	295 323	295 324	290 321
4	293 314	293 312	296 314	294 313	295 315	295 317	293 312
5	302 181	301 179	299 185	301 180	300 178	301 188	299 168

1: light on

0: light off

Construction of the look up table

The look up table between color atlas and screen display bases on the eyes of testers. The authors, in this experiment, realized deeply the effects of psychological and physiological situations of testers on the color recogniability. But the results will be greatly improved when psychological methods are used if a group of persons with normal sight and different age-level are selected as the standard observers.

The look up table between analogue output and color atlas can be set up through minimum color difference in uniform color space (△E). The colour difference is calculated as follows:

$$\triangle E=\sqrt{(\triangle \mathrm{I})^2+(\triangle \mathrm{II})^2+(\triangle \mathrm{III})^2}$$

Considering that the system can be as the color correction of color reproduction system. We managed these data in DBF database, in shich there are tristimulus values of color blocks, colorimetric coordinates, screen percentage, color difference and the look up table. A interface programme was designed for the future application. The project shows that it is possible to control the color difference between color atlas and its analogue outputs about 5NBS. This result of the project is usable for map reproduction. See Fig. 6

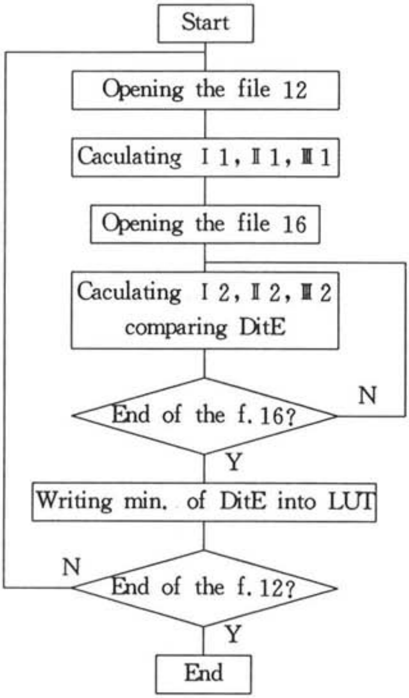

Fig. 6 The flow chart of setting up LUT

CONCLUSIONS

A technical revolution is being on in printing industry, since the late 1970s, due to the wide applications of computer in the printing industry, especially on preprocess procedures. In 1980s, following the use of computer image. This system is a preliminary research on dealing with problem of "WYSIWYG" in electronic publishing system. Form the point of application, the contribution of this research is as follows.

1. The black box method proposed in this paper is available to solve color degradation.

2. Conversion from RGB to YMC for reproduction has been finished in this electronic color atlas, it can really realizes the function of "what you see is what you get for color image".

3. The electronic color atlas also can be used as color correction in image reproduction system.

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BIOGRAPHICAL SKETCH

Prof. Zhang Qingpu, Director of Cartographic Department of Research Institute of Surveying and Mapping (RISM), was born in 1937 and graduated from the Moscow College Geodesy, Photogrammetry and Cartography in 1962. Since then, he has been undertaking cartographic researches for 30 years. Prof. Zhang is good at Map Reproduction, Computer Aided Color Design and Image Processing. At the moment, he is a member of both Tactile Mapping Commision and Standing Commission on Map Production Technology of 1CA.

Mr. Jiang Bin, born in 1965, has gotten B. Sc. (1988) in Cartography from Wuhan Technical University of Surveying and Mapping (WTUSM) and M. Sc. (1991) in Computer aided Cartograply from Research Institute of Surveying and Mapping (RISM). At the present, he is studying at International Institute for Aerospace Survey and Earth Sciences (ITC) as a Ph. D candidate, his research interesting is in Map Reproduction, Map Design Expert System, and Visualization in GIS.

A cartographic output-generator for an urban GIS of high resolution

E. Wilmersdorf (Wien, A)

Abstract:
This paper describes the transformation of a geomodel into a cartographic model emphasizing the postprocessing stage with automated construction facilities for generating sophisticated cartographic images. This procedure is the basis in the municipality of Vienna to install production lines for final map products decentralized in a network. But the process also covers the controlling of different outputdevices in order to draw maps on paper but also on colour separated films ready for high quality printing.

1. Introduction

Urban GIS are operating mainly in the range of large and medium scales. At a first glance cartographic problems seem not to be so complex as in small scale images. But the high density of objects and their manifold descriptive attributes in urban areas evoke cartographic problems as well when producing graphic presentations.

GIS technology alleviates the view into the urban microcosm with its relationship among objects, on the ground and underneath. Consequently thematic mapping is promoted as documentation of GIS analysis. Especially the quick display and the need of producing an instant hard copy enforce the demand for sophisticated cartographic modelling software.

As existing GIS lacks powerful facilities for automated mapping there is a need for a postprocessing according to cartographic rules. The city of Vienna bought and developed therefore software for computer assisted production of topographic and of thematic maps.

2. The components of the data base

Before discussing the procedures of the report generator the sources ought to be outlined, which are available in Vienna. As a general rule the data bases of the geo-model are designed in such a way, that they contain an abstract definition of geometry,as much as possible to be independent of scale and legends. There is also a set of data bases,geometric and alphanumeric, which work together.

2.1 topographic data base

The city of Vienna started a project, dealing with the data capture of topographic data systematically. The "assembly line" starts with digital tacheometric and photogrammetric survey according to uniform guidelines. There is a partition of tasks. The street area is covered by field survey as requirements concerning positional accuracy are tougher there. The bloc is filled with data measured by operators working on stereoplotters. In such a way planimetric data of objects are stored, furnished with Z-coordinates.

The data base is marked by:

*high accuracy
Field survey offers accuracy within a few centimeters, photogrammetry within few decimeters i.e ten times less. But this is quite good enough to cover with one topographic data base a scope of cartographic output from site maps 1:200 to the scale of 1:10.000.

*high resolution
the shape of objects is recorded in a very detailled manner. It was quite the same reason as in the case of accuracy: the data should fit the utmost requirements, to prevent multiply maintained topographic data bases.

*structured data
the topographic data are marked by a wide range of codes for object classes. Therefore an application oriented selection can be done in a flexible way.

*creating objects
The detailled view forces to split up compounds of objects into elements (e.g. front line of a building distinguished from the general outline).

*identification keys
In general topographic databases are marked by layers only. But additionally, objects can be furnished with identification keys. That alleviates the access into the geo-model, but also the linkage to attribute data bases.
e.g. pylons get a key for facility management.

2.2 Street network and bloc structure data base

The complete street network is stored in a schematic manner The streets are defined by a network based on the nodes of intersections and vertices. This model is fully geocoded (nodes, segments, adjacent bloc areas with reference to the postal address.

2.3 Cadastral map

The digital cadastre covers the legal aspect of topography

2.4 Thematic data bases

There are additional application's databases making use of the topographic data base

zoning model (regulations for building permission)
utilities (underground)
environmental aspects
land use
etc.

3.The generation of the cartographic model

3.1 The thematic model

In the first stage a thematic model is generated, which corresponds to the request of the user in terms of information. A logic and regional selection is accompanied by GIS analysis procedures, generating derived attributes and consequently new information. Objects of the geomodell get additional attributes (e.g. by statistic calculations) or new objects are founded by overlay intersections.

3.2 The cartographic model

3.2.1 Basic considerations

The next step transforms the thematic model into an cartographic one. This process refers on both components of the GIS database, the geometry and the attribute's collection.

For the building up the cartographic modell additional geometric objects are constructed, using the geometric definitions of the original object in the abstract geomodel. Either the new geometry replaces the old one (offset of a line) or it adds new objects (e.g.symbols) for graphic display.

4. Generating a cartographic model

4.1 geometry

The building up of a cartographic model is linked with many geometric changes and especially geometric complements, e.g.:

*windowing

scale and geometric clipping for a special window

constructing insets with enlarged presentation
e.g. the accumulation of objects is checked.
if the density is too high for the graphic
representation a port is created. Into this
port a zoomed window is put.
On the contrary if the window shows a small part a
standard inset with a general view in a
smaller scale can be added

*construction of additional geometry
parallel lines/axis
lines for dimensioning
offset lines of vectors for buffer zones

*generalisation of geometry
There is a set of rules which launches generalisa tion e.g,size of an area

It is essential that objects can be accessed by their key after the generalisation, so that the link with the attribute table is possible (e.g. a geostati stic about the age of a building) afterwards.

4.2 symbolisation In this process the model gets new object classes:

*attributes of an object lead to the generation of new cartographic object classes (e.g. new symbols are positioned as overlay)

*attributes are transformed into a cartographic attribute table (e.g. grouping)

4.3 Text positioning
In the abstract geomodel there are no text positions available. Key names and attributes are linked with the object's geometry but they have no separate graphic representation.

When cartographic parameters are defined (Window size, scale, map type) text placement starts. New geometric objects are constructed (text box for position, orientation and character size)

By a variety of parameters for algorithms and the construction of text objects can be chosen offering e.g. several possibilities to set street names:

*in the middle of each segment

*min/max distance between the next repetition

*at the beginning and at the end of a street

*shifted into the bloc, so that the street area is available for other graphic objects.

*orientation of text

But also the text string of the street name can be changed:

* abbreviations are permitted
In the street data base abbreviated names are

available. They are selected, if the space is too small for the complete character string

* separation into syllables
  e.g. street name at the beginning, the text string "-street" at the end

In the case of the street data base Vienna maintains a name register. It contains a code table for the full name and abbreviations.

The constructing of positions for text strings on call offers a lot of advantages:

* update of names
  e.g. by means of a stable key code new names of streets are inserted automatically

* exchange of text strings
  key code, name and attribute can be replaced easily. Thematic maps often uses attributes (e.g. number of inhabitants) or object classes (e.g. school) instead of key codes or names.

* The routines for textpositioning can be used for symbol placement as well

* text placement can be adjusted to the geometric window and scale.
  If an areal object is clipped by the map sheet the reduced polygon is the basis for the text place ment routine.

It should be mentioned that the GIS analysis tools are applied to support the text placement routines e.g. the width of a street segment or other attributes can help the adequate text height.

4.4 Generalisation

Generalisation can also be necessary in the case of larger scale presentation. High density and local relationship leads to complex presentation, so that existing generalisation routines don't fit the requirements for high quality output. In such cases interactive editing are still necessary. But it is envisaged to improve these routines so that "manual" interference for scale-dependent models is avoided as much as possible, at least in the range of 1:200 to 1:10.000. Therefore it is a goal that maps in reduced scales can be derived from one unique geomodell of high resolution by automated processing. This strategy forces the efforts to improve the rules and algorithms of generalisation. Isolated generalisation for one or more object classes are in production already, but the harmonizing of the overall image is not solved yet.

* Reduction of text
  If the streetname doesn't fit into the available space it can be compressed

* erasing of single objects
  the size of the cartographic object is too small or its attribute signals minor importance

* simplification
  e.g. alignment of the front of a building

* enlargement
  e.g. narrow streets can be blown up

* grouping of objects
  e.g. generation of groups of trees derived from an accumulation of single trees.

* Omission of text
  If the space is not large enough, text can be supressed (general by object class or indivi dually)

  e.g. postal adresses are numbered systematically in Vienna, so that some of them can be erased automatically in smaller scales. Therefore it is reasonable, to pick out the essential addresses (from/to address of a block side)

This illustration shows that a lot of rules can be applied to automate the generation of map images.

Finally it can be summarized that the modelling phase of the cartographic model consists of very complex processing. Many objects from the thematic model are modified and new ones are generated, new object classes for graphic purposes are inserted too. The GIS itself can be seen as a helpful tool, to automate the generation of a sophisticated cartographic modell:

geometric analysis
- *neighbourhood
- *dimensions (size, length)

attribute analysis
- *attributes of the neighbourhood
- *statistical examinations

4.5 The checking of the cartographic model
As mentioned before all these routines cover special tasks but an overall controlling of this processes could not be automated. Therefore the "draft" of this cartographic model must be checked, to reveal graphic faults e.g. collision of text and symbols, text and geometry.

If such faults are discovered an automated attempt can be made, to correct by shifting or by deleting, if the object is a member of an object class of minor importance. If this doesn't bring a reasonable solution the cartographic object is put onto a separate layer of the model. There it is available for interactive editing.

5.Output Phase

5.1 The output mode

In this stage the cartographic model is transformed into the digital map with its final shape. Pattern libraries are linked by tables with the object classes of the cartographic model:

Point symbols
Line pattern
area pattern
Text fonts

These data are transferred into a metafile. This is the source for different plotter driver software. The scope of output devices for cartography has increased. But because of the lack of world-wide standards graphic interfaces the generation differs much according to the specification of the output device (laser printer, pen plotter, electrostatic colourplotter,laserplotter). But it is essential, that not only paper work can be produced automatically but also a production line from the GIS-station to a sophisticated Laserplottersystem can be installed. In this case additional processes for masking, screening and colour separation had to be done.

5.2 The control of process

In order to bring automated procedures running without interference, an "assembly line" must be designed according to the type of cartographic output. That means that at the beginning the processing modules from the software library must be chained together, parameters must be defined and symbol,text and pattern libraries be attached.

In such a way prefabricated production lines had been installed, which start in the thematic model of the GIS and lead until the map is printed out on paper work or on film for the printing plate. This approach is suited for individual products and for map series as well.

In order to accelerate the response time, plotters had been installed distributed in different branches of the urban administration. They are linked via a network with the computing center. On the working place the plots are launched, over network the data base is linked and after processing the plot file is sent over the line to the plotter. The plot production is executed without operators, as automatic paperfeed is available.

6. Final remarks

Analysing the output of all these production lines it is evident that the trend goes towards purpose oriented output made to measure. The increasing user group profit by the flexibility of GIS selection and by the flexibility of an digital cartographic model.
The efforts of software development concentrate on the improvement of cartographic knowledge in the computer. Meanwhile the dissemination of automated production is increasing, promoted by rising GIS use. Automated production facilities of high quality maps seems to be the adequate response to the challenge of wide spread GIS technology.

An end-user GIS for flood risk determination

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Abstract

Whenever real property in the United States changes hands, is refinanced or is subdivided, a complex and costly sequence of investigations and decisions is initiated. Banks, insurers and government agencies must determine the nature of the properties in question, their putative owners, liens and other legal encumberances, and environmental conditions such as the presence of toxic materials, including chemical waste, asbestos and lead paint. A factor of unique importance to buyers, sellers, lenders and insurers is a property's risk of experiencing flooding from rivers, lakes, wetlands and dam accidents. Because the U.S. government underwrites flood insurance, it has a particular interest in determining the risk of flood, as do fiduciary institutions engaged in the transfer of real property. To make flood risk assessment procedures easier and more uniform, the Federal Emergency Management Agency (FEMA), an independent federal authority, has launched a multi-year project to develop a specialized geographic information system (GIS) for this task, assembling easy-to-use applications and complete cartographic and attribute databases, and packaged for distribution on CD-ROM media. Users of this package – which runs on various hardware platforms and incorporates a graphical user interface – will typically be banks, mortgage companies, title insurers and government regulators. The principal function that the system performs is the determination of whether a property at a specific street address is within the one hundred- or five hundred-year floodplains. In order to assess this, the software accesses a national street map including address ranges, contours of floodplains and other data. The basic organization of the database and software are outlined, and the function and logic of selected applications are described. Other topics addressed include data base creation, risk and uncertainty management, quality control and human factors engineering. Graphic examples illustrate the user environment and cartographic displays generated by the system.

Session 15

Space and Map Perception and Language Representation

Chairman:
T. Morita, Kokusai Kogyo Co., LTD (Tokyo, J)

Theoretical issues in cartographic modeling

V.S. Tikunov (Moskva, CIS)

INTRODUCTION

Modeling is one of the more widespread concepts in science. Originally, the word "model" referred to a reduced copy or, as V.I.Dal', the Russian lexicographer, put it: "a depiction of something in small form" (Dal', 1881). Later, "model" came to be understood more broadly as "any image (mental or conventional, such as a representation, description, chart, design, graph, diagram, map, etc.) of an object, process or phenomenon (the original of the model), used as its surrogate". In its turn, modeling has been defined as "one of the basic categories in the theory of cognition, the idea of modeling essentially providing the basis for any method of scientific investigation, both theoretical (using symbolic and abstract models) and experimental (using physical models)" (Soviet...,1981).

In Russian cartography, the notion of maps being models arose only relatively recently (Stefanov,1964; Salishchev,1967), but soon found wide acceptance. Although there are many views regarding the nature of maps (Ratajski, 1970, 1972, 1978; Aslanikashvili, 1974; Lyutyy, 1981; Pravda, 1982; Ostrowski, 1984), no one seems to reject the thesis that a map is a model. A map as a model reflected the objective real world through a cartographer's subjective understanding and perception.

The cartographic literature often uses the term "cartographic modeling" (Aslanikashvili, 1974; Salishchev, 1982; Berlyant, 1986) even though there is no general agreement as to what is meant. For example, the Moscow University cartographer A.M.Berlyant said recently "We interpret 'cartographic modeling' as the creation, analysis and transformation of cartographic products, the surrogates of real-world objects, with a view to using them to gain new knowledge about these objects. It should be emphasized that the term 'cartographic modeling' is justified mainly in a theoretical -methodological context and not as an equivalent of the terms 'map design and compilation' and 'map use', as is often done" (1986, p.21).

In accordance with the point of view, formulated in (Salishchev, 1982). The substantive approach to cartographic modeling includes the modeling of the study object by a variety of means. According to this view, new knowledge acquired, say, by matching soil and vegetation contours on maps and producing a resultant map of relationships, can be gained both within the particular thematic disciplines in geography and within cartography. Such a broader view of the scope and the tasks of cartography makes it not only a methodological discipline, but an objective science in its own right. In contrast, say, to the concept of metacartography (Aslanikashvili, 1974), which is concerned mainly with map compilation, the substantive approach to cartographic modeling would encompass not only map compilation, but also map use.

Another view was held by the late Georgian cartographer

A.F.Aslanikashvili. "To be a subject for mapping" he said, "is not the same as being a subject for cartographic modeling. The fact that the space of a study object may be a subject for cartographic modeling does not necessarily mean that the content of that object also becomes the subject for modeling. On the contrary, the content of study object does not lend itself to cartographic modeling, since this is a unique form of modeling that is suited only for the representation of space and of spatial forms and relations, and nothing else" (1974, pp. 104-105).

TECHNOLOGY OF MODELLING

The technologies of modeling the geographical systems depend first of all on the collection of data and their territorial localization. Of course, publications, statistic and cartographic materials, aero- and space images are widely used in geographical research, while the means of complex geographical monitoring of environment and society are constantly improving. The most dynamic renewal is typical for the remote sensing data. Modern sensors can be passive or active; passive sensors catch the reflected or emitted natural radiation, while active ones send the necessary signals themselves and record it after it has been reflected from the object. Passive sensors include optic and scaner devices operating in the interval of reflected solar radiation (ultra-violet, visible and near infra-red bands); radars, scanning lasers, microwave radiometers and other devices are classified as active sensors. The modern trend in the development of operational space electronic systems of remote sensing is to combine various multichannel and multipurpose sensors with high resolution, including the all-weather equipment. Together with them non-operational space systems with panchromatic photo equipment and multispectral cameras providing high resolution and geometrical precision are still in use (Permitin, Tikunov, 1991).

As for the spatial regulation of data it is important for the unification of data collection as well as for the determination of their optimal accordance with the dimensions of systems under study. Some data are fixed to points or to lines which are given by coordinates of their points. Sometimes they are fixed to the territorial administrative units or to natural contours, for example, river basins. Good results were obtained by fixing the data to landscapes. But for compiling integral ecological maps it is the most useful to work with the objects known as natural-anthropogenic systems. They are defined as spatially and temporally limited complexes formed due to economic and social activities of population within a particular territory with characteristic geographical location and features of geographical environment, including both man -made and natural objects and phenomena (Nevyazhskiy, Tikunov, 1991). To our opinion, natural-anthropogenic systems should be principally interpreted as inseparable, totally integrated objects which can be "divided' only for studying various processes in their components. Structurizing of spatial data requires the wide application of geoinformation technologies including rastre and vector formats allowing the transition from one to another, as well as the combined forms of data presentation (Chukin, 1983; Shapiro, Haralick, 1984; Samet, 1990; Tikunov, 1991, etc.).

In modern geographic technologies the data processing is no longer an ordinary matter; it requires the application of various mathematical models. The spatial aspects being of primary importance to geography, 3 types of models can be distinguished: 1)mathematical models are elaborated without the account of spatial coordination of phenomens, their results are not to be mapped; 2) the results are mapped, but the spatial aspect isn't taken into account while realizing the mathematical algoryphms; 3) the mathematical calculations cannot be performed without the account of phenomena location (Tikunov, 1986, b).

Among the great variety of models used in geography mathematicalstatistical, simulation, optimization and mathematical-cartographic ones have become the most widespread. Let us first of all note the worth-while methods of "spatial statistics" (Vasilevskiy, Polyan, 1977; Griffith, 1987), because the available mathematical statistics is unpracticable for geography. It is necessary to expand the elaboration of methods of spatial mathematics and even more - the spatial modelling or, more correctly, the spatial and temporal modelling, taking into account the spatial and temporal character of geographical phenomena.

The mathematical-cartographic modelling (MCM) is one of the types of such modelling (Zhukov, Serbenyuk, Tikunov, 1980). The MCM is defined as the organic unification of mathematical and cartographic models within the system of map compilation and use for the sake of designing or analyzing the thematic content of maps. The aim of combined modelling is to utilize the strong aspects of each component. The mathematical-cartographic modelling makes it possible to construct both elementary one-link models and complex combinations such as chain, network and tree-like models (Tikunov, 1985), in which alternating mathematical models and maps allow to optimize the process of modelling, to correct it, to find likely mistakes, etc.

The technology of modelling the geographical phenomena can have a multiversion character, which can manifest itself at all stages of modelling including the information supply, data processing and representing the results of modelling (Tikunov, 1990). The stage of information supply can include the use of various information blocks for description of one and the same phenomenon. It is especially important for the description of abstract notions such as, for example, the level of social and economic development of the countries. This notion cannot be characterized by a precisely fixed set of parameters, because it is interpreted differently by various scientists; though the existence of distinctions between the countries and the possibility of their description are not disputed. It is possible to use different systems of initial parameters processed according to the same algorythm and represented in the same way on maps; in this case the reliability of results depends only on the information supply of modelling.

The multiversion character can also manifest itself when an information block is processed according to different algorythms. In this case one should be aware that all algorythms correctly reflects the nature of modelled phenomena, as shown for example in the article (Tikunov, 1982). The accuracy of results obtained through different algorythms should also be taken into account; it should be approximately the same if one is going to obtain the common final result. Otherwise the results will have different reliability and require different "weight" indices, though such assessment is often complicated in itself. Application of different mathematical methods to obtain a single final version becomes more and more widespread being promoted by expansion of computers and improvements of program libraries devoted to modelling.

The third aspect of multiversion character of modelling is connected with different ways of mapping of its results. The language of maps is very rich and profound; it has been used for centuries but still new ways of graphic representation of phenomena on maps appear today and this process will undoubtedly continue. A certain leap in the elaboration of new types of data presentation is connected with the automated reproduction of cartographic images.

The next important task is the assessment of reliability of modelling. We distinguish between the technical accuracy of mapping and the reliability which characterize the correspondence between the geographical phenomena and their cartographic models (Tikunov, 1982). In order to determine the factors of reliability it is necessary to describe the whole process of modelling, from map design to selection of the ways of presenting the results because all technological stages provide a certain impact upon the reliability of thematic content of maps.

The reliability can be connected with the multiversion character of modelling. Thus, providing for simultaneous use of various information blocks, different mathematical algorythms and ways of presenting the results, the multiversion character leads to the higher reliability of the final result. This statement is proved in the work of Serapinas (1983) who showed that two independent versions having the reliability of about 0.684 provided the final result with reliability increased to 0.900. In this case the possibility of obtaining the reliable result is evaluated according to the formula (Kapur, Lamberson, 1980): $P=1 - \prod_{i=1}^{n} (1-p_i)$, where p_i is the possibility that the independent errors of each version of study do not exceed the permissable limits. However one should take into account that too large number of versions stops the increasing reliability of the final result. The mapping of reliability of modelling results is worth-while as it shows the different accuracy of various parts of a map (Tikunov, 1982, 1985).

The general reliability of modelling is connected with geographical reliability which is determined by the way the geographical problem is put, the choice of the optimal parameters for the study, the thorough and informal interpretation of the results of modelling (Tikunov, 1982, 1986, b). In the process of modelling the intermediate results (mathematic correlations, maps at different stages of modelling) are constantly correlated with reality in order to correct or supplement them (Tikunov, 1985, p.155-158). At the stage of interpretation the geographical features of the object under study determine the general assessment of results and compiled maps, the principles of their meaningful interpretation, the character of practical and methodological recommendations.

MODELING PROBLEMS AND EXPERT SYSTEMS

If working with data was previously considered to be one of the tasks of computer processing, with humans understanding the meaning of all manipulations, then the attainment of the goal of creating the programs capable to analyze the semantics (the meaning) of the data used requires the application of knowledge bases. Such programs are capable to create the chains of interference based on conclusions made earlier, filtering knowledge as if "through" these conclusions, verifying its logic, refining it and creating more elaborate constructs. If the obtained result obviously contradicts common sense, this will make no difference to a computer employing an algorythm, but in an expert system such a situation cannot go undetected. Moreover, the systems of artificial intelligence, capable of self-training with the use of experience in analysis, control and decision-making accumulated in the process of studying the real phenomena, can produce the second level knowledge or metaknowledge (Waterman, 1986).

There are several kinds of expert systems used in geography. Among them the cartographic expert systems held a great share that can be explained by the complicated nature of cartographic images which require the logical co-ordination between their elements, their correlation with the reality, complex formalization of compiling techniques, etc. All these things are called the cartographic erudition which is gained by a specialist as his own amount of accumulated knowledge. Application of knowledge gained by experts already allows to create the cartographic products which correspond to those compiled by specialists of rather good though not the highest qualification. First of all it applies to the formation of conventional sign system for a map. Their combination should be optimal to characterize the phenomena represented on the map. Therefore it is necessary to consider a lot of factors, such as the possibility of combining various mapping techniques (for example, while describing several parameters of point-located objects), probable overfilling or undersatiation of maps which depend particularly of sign size, a esthetic harmonization of color design, correspondence of signs and labels and lettering to approved normatives, type of their location, alternative map arrangements, etc.

Expert systems can help the cartographer to determine the type, the size and the color of conventional signs while co-ordinating the content elements, adding and designing new signs, revealing the mistakes in map digitizing, discerning the cartographic images, interpreting photos, etc. (Schenk, 1988; Yue, Zhou, 1980; Zhou, 1989; Zhdanov, Martinenko, 1989; Muller, Zeshen, 1990; Raasch, 1990; Zhang, Su, Li, Zhang, Liu, 1990). The renovation and editing of marine navigation map performed at the Department of mapping and geodetical service, National ocean service (Bossler et al., 1988) provides a good example of such application of expert systems. There is a positive experience of applying expert systems for the automated cartographic generalization (Zhang, Li, Zhang, 1988; Zhao, 1988), as well as for the selection of map projections (Nyerges, Jankowski, 1989; Smith, Snyder, 1989).

Another type of cartographic expert systems concerns the modelling of thematic content of maps. In this case there are the scenarios of geographic phenomena evolution due to a lot of factors which are modelled and which form the main content of map. The example of this type is an expert system for the ecological and geographical examination of alternative places to locate an industrial plant through assessing the possible impact on the environment and for the compilation of prognostic ecological and geographical maps for the polar regions of Russia (Bogomolov et al., 1990). In the first case the metric characteristics of a map are the most important and in the second one it is its content which attracts the main attention though in both cases the space and the content are closely connected.

The expert systems will be more useful for the geographer if they contain non-ordinary information about the results of similar activities undertaken somewhere (or once) under similar conditions. It is possible that the recommendations about rice growing as expected from the expert system by the rice grower from the Krasnodar territory of Russia will differ from those expected by the rice grower of Guandun province of China. But one can imagine a scientist interested in geographical concepts of crop growing as they are, notwithstanding the results of their utilization (Babushkin et al., 1991).

The important feature of expert systems is their ability to work with "fuzzy" knowledge, which results from "fuzzy" definitions used by geographers. For example, considering the notion "a wide river" we know for sure that for different people, say in the desert or in the Amazon valley, the size of such a river will differ considerably. The facts are described using "fuzzy" logic, the indices of certitude have been elaborated to evaluate the extent to which each conclusion can be trusted.

We say it is possible to work with 'fuzzy" knowledge; but even for "fuzzy" data the technologies of their application in geography are elaborated quite inadequately. Among the typical examples of "fuzzy" data there are many remote sensing materials, imperfect statistical data, etc.

There is a problem of how to describe the indistinct or "fuzzy" boundaries, particularly typical for natural phenomena. While mapping such phenomena this problem isn't yet properly solved. Despite several attempts (Yee, 1985; Andreev, 1987; Rolland-May, 1987; Zhaozhong, 1988; Tikunov, 1989; Wang, Feng, 1989) this sphere of cartography is yet poorly studied. Even in relatively simple cases of gradual changes of phenomena (Fig 1.a) the techniques shown on Fig.1. b, c, d are used more often than that on Fig.1.,f,g.

Various classifications widely used in geography also have the elements of fuzziness. Geographical publications have several times pointed out that the methods of the theory of fuzzy sets are quite useful for these purposes. According to this theory, proposed by L.A. Zadeh (1965) and improved by other scientists, it is possible to attribute territorial units not only to one of the given classes (as standard algorythms of multidimensional classifications) but to several classes with different functions of belonging (in the case of transitional nature of units)*. Such classifications are quite purposeful when the real boundaries are fuzzy and transitional and it is necessary to consider this fact in the process of mathematical modelling and to depict it on geographical maps. The indistinct character of boundaries is sometimes regarded as their common feature (Trofimov, Solodukho, 1986; Rolland-May, 1987).

One should pay a special attention to the following statement: "It is necessary to point out the fact which has a vital importance. The classifications based on indistinct measurements of identity should always be regarded as only more or less acceptable and reasonable, as the lesser of two evils typical for the situation requiring the grouping of objects which can hardly be described or cannot be at all described by traditional means of formal characteristic. The matter is that such classifications have "fuzzy" nature themselves, therefore speaking of the identity of their results is quite senseless" (Trofimov, Solodukho, 1986, p.20).

Let us notice that the indistinct nature of a phenomenon can manifest itself even without the direct use of the theory of fuzzy sets, within the traditional methods of geography. In our opinion, the geosystems are interpreted as fuzzy complexes due

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* We do not analyze the methods of the theory of fuzzy sets here.

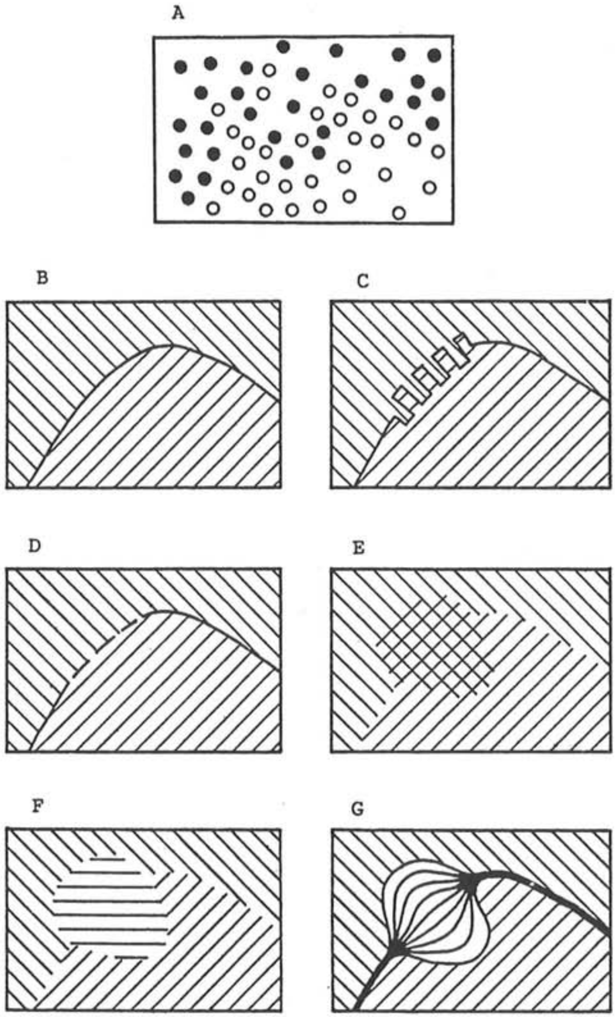

Fig.1. Examples of representing the indistinct boundaries.

to several reasons. Indistinct nature of a system can manifest itself while: 1) describing it during the process of determination of classification tasks and aims; 2) choosing the system of parameters to characterize it; 3) selecting the classification algorythms; 4) selecting the results of multyversion classification; 5) choosing the ways to present the final results; 6) assessing of how the results meet the aims, and interpreting the conclusions (Tikunov, 1989).

VISUALIZATION OF DATA

Modern technologies provide for various output of data for geographical studies, such as tables, summaries, selections, files on machine carriers, prints on paper, or schemes and maps. Both "paper" and "without paper" technologies are used in these cases, the latter meaning the reproduction of maps on the display screen, for example. It requires the elaboration of special means of computer graphics, on the one hand, and the adaptation of mapping techniques, on the other hand. Map compilation on the display screen allows to check numerous versions of map content and design. Moreover such technique is quite suitable for the demonstration of phenomens dynamics, for example in the form of cartographic films when the maps replacing one another reveal the course of a process. Another way is the animation of individual symbols, for example, blinking of points or signs or their movement around the screen. The development of dynamic computer cartography requires the elaboration of special symbols, principles of image generalization, etc., with the account of psychological and physical aspects of their visual perception. It is rather important that the image can be copied from the screen to the paper, so the "hard" copies can be obtained. The availability of a great number of personal computers capable to reproduce hundreds of color shades provides for the wide spreading of such "without paper" technique of mapping. Interesting results are obtained using animated films, for example, for imitation of dynamic situations in environment pollution (Molotchko, 1987).

The intense work is carried out to elaborate 3D-images, such as block diagrams, anaglyphs and stereomaps. The special attention is again attracted to holography which allows to reproduce 3D-images depicted on holograms - photographic plates fixing the results of wave interference. The holography has been used in geography for rather a long period of time though not too widely. The example is the representation of settling of the USA territory during 180 years (Dutton, 1979) and the study of forests using holographic techniques (Pavlova, Korneev, Tchalov, 1984). The present situation can be explained by inadequacy of special equipment at geographical institutions.

Other non-traditional images include mental maps, maps of preference and anamorphoses (Gould, White, 1974; Tikunov, 1986,a etc.) which are rather widely used. 2D anamorphoses are intensively elaborated and used; they are derivated from traditional maps through equalization of a certain density (of population, spatial distribution of incomes, consumption of some products, etc.). The areas of territorial units are proportional to the values of parameter which is used for constructing the anamorphosis. The location of territorial units and their shape are kept up as far as possible (Gusein-Zade, Tikunov, 1990). Fig.2 represents an ordinary map of the former USSR (state area as in 1990) with the data about hepatitis rate in 1970-1985 shown within the territorial administrative units. Fig.3 shows the anamorphosis based on the number of population in 1990 with the indices of hepatitis rate also put on it. The comparison of Fig.2 and Fig.3 proves that the anamorphosis gives more adequate picture of decease rates because in this case they are related to population and not to the area of units as on Fig.2.

Fig.2. The map of the sick rate of the infectious hepatitis in the USSR in 1970-1985.
Sick rate (per 100 000 residents):
1 - low (<200), 2 - middle (200-400), 3 - heightened (400-600),
4 - high (600 -800), 5 - very high (>800).

Several words should be said about the technology of multimedia which integrates achievements of different sciences into the field of GIS in order to make the perception of spatial data more multiform. For these aims materials from data bases are integrated into a united system with cartographic images, photos and so on, the review of which is accompanied by sound signals. For example the orientation among streets is easier if the user gets possibility to see on the screen of the monitor some outstanding buildings in streets or if only corner houses in the form of photos, moreover accompanied by the noise of central main streets or other city sounds, what just emphasizes the sensation of a reality. Here the influence on organs of sight is combined with the influence on the hearing, and in a perspective will be supplemented by influence upon organs of smell too. For example it will be possible to feel the smell of a forest, of a field. Businessmen will use GIS more frequently if they will permit to feel the smell of oil and so on. However it will require more specialized equipment. At present the equipment includes, as a rule, three-dimensional graphics, video movies and stereo-sounded accompaniment.

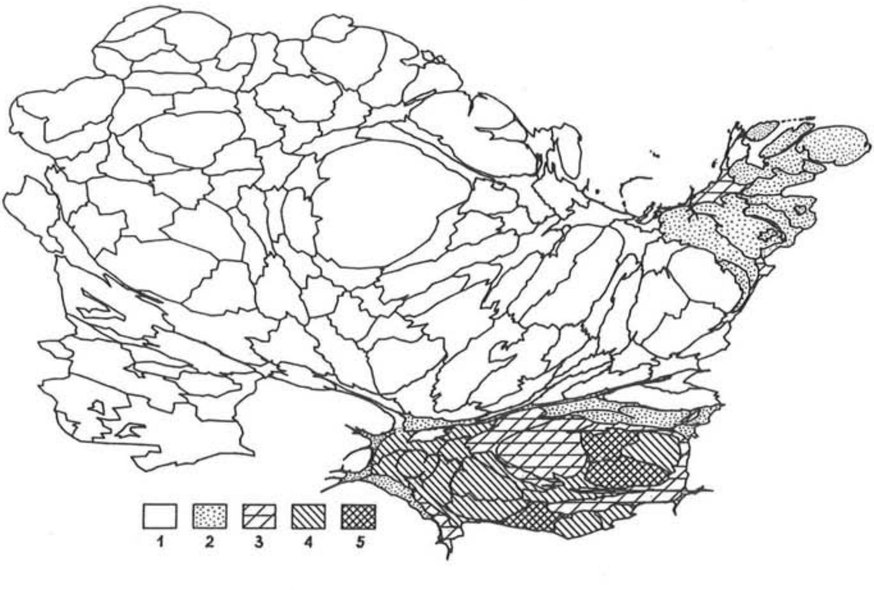

Fig.3. The sick rate of the infectious hepatitis shown on the anamorphosis of the USSR based on the data on the number of population (1-5 see fig.2).

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A semiotical approach to typology of the map signs

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INTRODUCTION

For a long time, it can be said, up to 1925 the cartography played only a part of a practical auxiliary hand skill, particularly in geosciences, warfare as well. Once upon a time every institution whose task was to investigate the object, phenomenon or the relation between them from different aspects conceived their maps themselves for their own necessity, often not to be conscious of their product that was a communication tool. Even so, here it must be given into the bargain, not only good maps were achieved but also bad products so far. The works of M. ECKERT[6] provided a new dimension to the cartographers. He was the first scientist who spoke from science as regards cartography.

As noted above since maps were produced for your own clearly defined usage purpose there was no point in considering different expectations of different user groups.

From 1940 on the map user has became a subject of cartographic investigations[13], but first KOLACNY worked out a model of a cartographic communication[9]. His works inspired further valuable researches and discussion on that theme. A brief look at the literature on theoretical cartography during the past three decades shows a noticable persistent increase in the works dealing with the different aspects of transmission of spatial information by means of maps. Several papers, even doctoral dissertations have been devoted to this, at first sight, theoretical topic of cartography, however, it lets hope to us to derive practical conclusion to the map design as well.

Since to cartographers there is no doubt that the map is a communication medium for transmission of information on spatial objects and phenomena, it is our Sisyphean task to make more efficient this communication from cartographers to users, distinguishable, once again, pursuant to age, social position, education etc.

As it is well known communication can occur only by means of signs. The term "sign" should be understood in the broadest sense. The sign definition given later covers all things which in some way take a part in any communication process, at first between human beings.

As it has been already well known the research of all kinds of signs, especially the signs of natural languages, it is the subject of a rather young science, semiotic, otherwise spoken the general theory of signs. It attemps to accomplish its investigation from three standpoints:

1- At the first sign as such, as material things. It is just syntactic.

2- At the second level the relation between sign and object (in the broadest sense of this term, concrete, abstract objects or phenomena) which is represented by means of any sign. This point of view is called semantic.

3- The third relation between signs and the human being who create it, particularly consume it by way of gaining information. Technically speaking it is called "percipient" in a communication act. It is the pragmatic aspects of signs.

For space reason any further information is not given here. Detailed information on these relations are to be found in BENSE#s works [1], [2], [3].

SYNTACTIC OF MAP SIGNS

I must in advance point to that the investigation into the semiotical aspects of a sign system demands the highest attention with the dealing of the terms, since they are used in more different philosophical ways than in daily usage. Even though I try to take great effort on using the right term. Nevertheless, some painful choosed terms could arise. Therefore the suggested term now and then in view of cartography should be seen as provisional, i.e. discussible. We will just see an example in the next paragraph.

As has been noted above adequate to syntactic in the scope of general sign theory and in agreement with FREITAG[8] what we mean by "syntactic of map signs" is the investigation into the scientific nature and their structural traits and the design rules of them and maps.

The syntactic that attemps to accomplish the task mentioned above regarding the signs in the cartographic communication, therefore will be called "syntactic of map signs". Syntactic belongs to semiotic and there can be only "semiotical syntactic". Because of that we will avoid to speak from "cartographical syntactic"[17].

The material development of a map sign as a syntactical process can not be found as an isolated act from the other two aspects, i.e. semantical and pragmatical. Therefore semantical and pragmatical aspects of map signs are only discussed so far as is necessary for the goal of this paper.

ELEMENTARY UNITS OF MAP SIGNS

In the sense of syntactic each sign of a sign system can be cut up into minimal units which has a function in the transmission of information anyway. For example in the communication by means of language (MORSE-Alphabet respectively) the written letters that can be regarded as the minimum units of language do not need to have any meaning.

By way of communicating one can compound a new sign representing new information from minimal units. For example in language words from letters, sentences from words and so on. In the sysntactic this process is called "superization".

In contrary to the thesis that the minimum graphical units of the compounded map signs were "point, line and area" the standpoint should be taken in this paper that the graphical variables(size, shape, orientation, colours, value and texture or pattern) should be regarded as minimal syntactical units of the map sign system.

Indeed it is indisputable that the signs developed from these variables can occur first only by means of points, lines and area. That is valid to letters of the written language as well. But there one speaks on no account that points, lines and area are minimal elements. These graphical tools do not belong only to the map sign system. They are generally for every kind of graphical sign system such as letters, figures, architectonic drawings, diagrams etc. and even for map signs. Therefore points, lines and area legitimately called "implantations of plan", generally[4]. BERTIN's work[4] has blazed a trail in the syntactic of graphical signs, at least in the syntactic of map signs [4], [5], [16].

The graphical variables of the map sign system can be compared the best with the letters of written languages. This must not be overlooked as there is a great semantical discrepancy between them. While a lonely letter in a word has not any meaning, each graphical variable involved in a compound map sign, could be adjoined to a meaning(information) that could be in most cases expressed by a word or a sentence in natural languages. The following example should make it clear.

Assumed that the legend below would be made up for the boundaries in a map, scale 1: 500 000 of the Federal Republic of Germany.

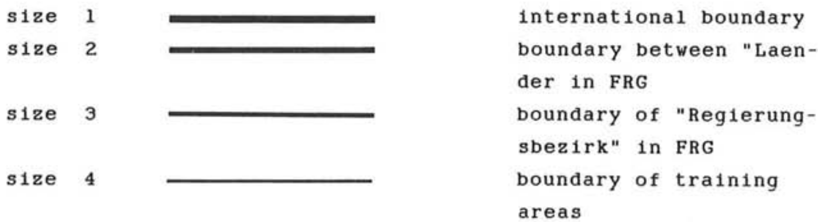

Figure 1 : Representation of boundaries by a graphical variable

Here the information to be transmitted are conveyed by using only one graphical variable, i.e. the size(line thickness in this case). As seen in each variation of line thickness coincides with other kinds of boundaries, i.e. a meaning expressed by means of a word, not by means of a letter. In the real map mentioned above, these line signs were not used, but the following signs in Figure 2.

size 1	international boundary (line screen in red)
size 2	boundary between "Laender in FRG
size 3	boundary of "Regierungsbezirk" in FRG
size 4	boundary of training areas

Figure 1 : Representation of boundaries on the map 1: 500 000 of FRG

As it can be seen here, two variables are used to code the different kinds of boundaries, i.e. the size with seven variations(four in the length and three in the width of the line pieces) and four pattern variations(dotted line, screened, a dash and a point combination, a dash and two point combination).

In the terminology this process, developing from minimal signs to a compound sign called developing a supersign or "semiose"[18], [7]. Examples for the developing of other supersigns in the cartographical communication were shown in the works by UCAR[18], and PRELL[11].

On a exact inspection could be seen that all graphical variables of a compound sign do not need to correspond any information. In view of syntactic and semantic the variable size is actually enough to code the information on the kind of boundaries. Any four variations of a graphical variable, for example only four different line widths, could be sufficient to code the information to be transmitted. The other three size variations and four pattern variations-semantical viewed-are not information conveyor. They are involved in the compound boundary signs to make the signs more distinctive from each other. Hence it follows that the cartographer regards it necessary for the legibility of the map. These kinds of sign can be called "redundant". This syntactical redundancy is in many cases indispensable for the interest of a rapid and unmistakable gaining of information existing on maps, even though in this way the map is additionally loaded.

It is no doubt that such redundancy can be met in the communication by means of natural languages. For example the English word "map" might be split up in the Turkish as city names "Mugla, Ankara, Paris" by way of preventing a false understanding. i.e. in favour of a true communication as possible as can be.

THE PLACE OF MAP SIGNS AMONG THE SEMIOTICAL SIGN TYPOLOGY

Since the mediums conveying information by means of maps are seen even as signs in the sense of semiotic. It should be possible to order them into existing sign typologies.

Charles Sanders PEIRCE was the first scientist who had attempted not only special traits of signs such as but also their relation to the object represented by them and its relation to the human being, i.e. to the sign creater, particularly to the sign consumer, technically speaking to the sign interpretent, percipient in a communication act respectively.

The sign typology of PEIRCE was developed again by BENSE[1], [2], [3] and by WALTHER[18]. Here the comment of E. WALTHER might be seen that the sign typology of PEIRCE raises difficulties for human comprehension as a sign type does not definetely and exactly belong to one class. Therefore his sign typology will be no subject for this paper.

SIGN TYPOLOGY GIVEN BY SCHAFF

A. SCHAFF[14] takes the task of signs to transmit information as a basis for the sign definition. "Every material thing, its components or an event will be a sign, when they are used to transmit any information on the reality, i.e. on outer world or inner life (emotional, asthetical and volitional experiences) of one of the participated partners in a communication act and in the scope of accepted language by communication partners". A similar definition stemed from RESNIKOW[12]. "The sign is a material and sensually perceptable thing(phenomeno, impact) that represents an other object or objects in a cognition or a communication process and is used to gain, to store, to change and to transmit information on these objects". We should remember these definitions for the typology of map signs. But the general sign typology will given at first.

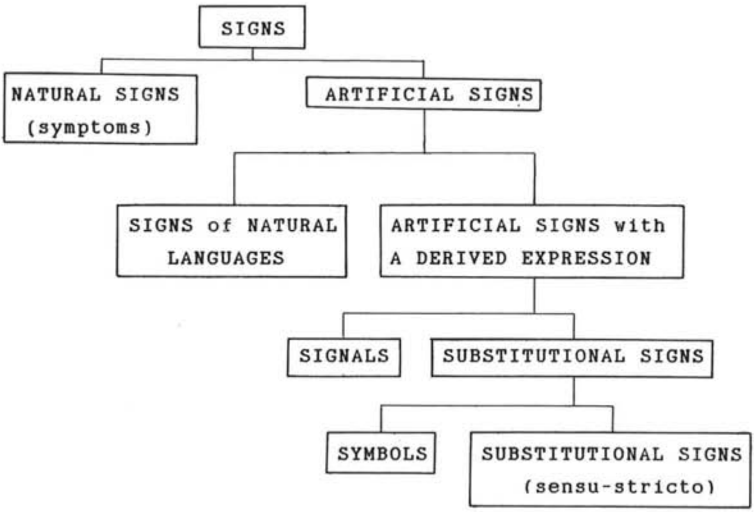

Figure 3 : Sign typology given by SCHAFF

SCHAFF[14] takes the way, which signs represent what kind of information as a basis for his sign typology. That means that here the source of information and the traits of represantation play a important role. A similar sign typology was made by RESNIKOW[12]. The differences between two typologies will not be discussed here. It might serve our purpose to retain in our mind that both scholars tacitly assumed that human being participate anyway in the communication act. It occurs between the human beings, i.e. between cartographers and map users.

The difference between natural signs and artificial signs consists in that the artificial signs exist independently of a delibarate communication action, whilst an artificial sign is a conscious human product and created for a purpose to represent any object and to inform on that object respectively. Therefore natural signs will not be the subject in this paper. Only the important traitsof artificial signs from our standpoint will be considered later wherever it is necessary.

TYPOLOGY OF MAP SIGNS

In view of the typology of map signs the cartographers produced a lot of terms which differ less or much from each other. For example representation medium, representation element, cartographic expression medium or derived, graduated, abstract, symbolic, pictorial etc. map signs.

In the opinion of the author to referring both of syntactical and pragmatical aspects for the typology of map signs might be little instinctive beacuse those relations between signs and objects represented or information conveyed by signs. That means that only the semantical, the informative aspect of the signs could be useful. It can be clearer to nature of map signs. A such typology of map signs should satisfy at least the following demands:

- The grade of the iconability of map signs should be exactly enough to be taken into account
- The difference between graphical variables representing any information and graphical variables representing no information (syntactical redundancy) should be emphasized.
- The typology must stand out by its uniformity
- The terms should be little different from used terminology in the cartography so far.

The proposed typology below may cover those conditions. Furthermore the advantage of this typology of map signs is that it considers the fundemental differences of the map signs in view of their representation way and the traits.

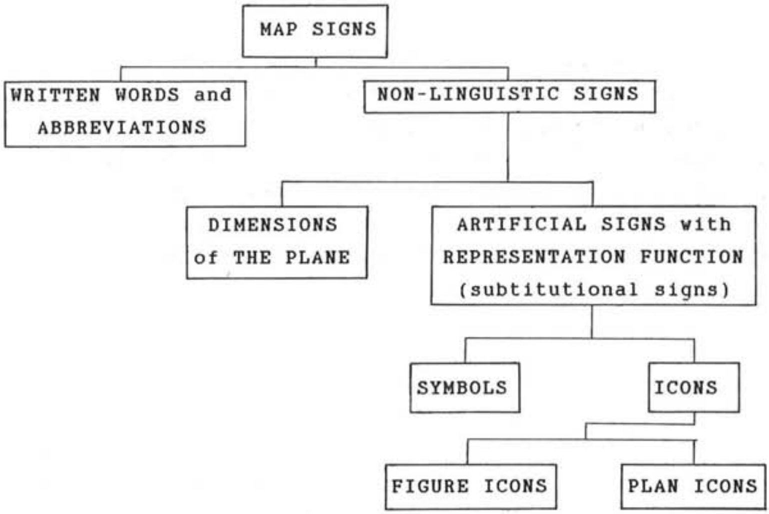

Figure 3 : Typology of map signs in the point of view of semiotics

In many cases the natural language is not well enough to transmit spatial information sufficiently. The cartographers even use the written words in their communication media. However, there are many aggravating differences between words in a text and the letters or words in the surface of a map sheet. It should not be considered here how the natural languages accomplish their task to transmit information of daily life and countless special fields. We should rather deal with their role on the cartographic communication.

In the map field, particularly for the topographical contents, the written words are used just only for proper names of regions, cities, lakes, mountains etc., as the naming always can occur on the basis of a natural language. In this sense the writing can not be suitable replaced by other signs used in the cartographic communication. Indeed from the position of signs on the map the objects represented by those signs might be concluded. But the map users can not have this preliminary knowledge on the respective region. Besides the cartographers can code many other qualitative information on the represented object by adding different syntactical subsigns for example size, colour, letter font, letter thickness etc. That is the crucial difference between word signs in a text and the word signs of the cartographic communication. It should be always retained in the mind. Once more it stands to reason that word signs on the map sheet should not be regarded as a foreign element of the cartographic communication. They are, so to speak, assimilated by cartography. They make it at first clear which region, which theme, which objects and which information are actually concerned on the map.

Some remarks to the dimensions of the plan. The function of a isolated map sign from the map contents consists in only the representation of an object or representation of further information. After the placement of signs pursuant to the spatial interrelation of the objects represented by these signs, the communication gets first cartographic. This must be regarded as a main motive for incidence of the map as a communication tool for spatial information. It is just crucial advantage of maps compared with the other information media in view of transmission of information on the spatial reality. As the dimensions of the plan convey locational information on the objects it is justified in the sense of the semiotic to treat them as signs under consideration of the sign definitions given before. The properties of the plane in view of the information transmission were dealed and epoch-making investigated by BERTIN[4].

The majority of the map signs is constituted by signs which are called "substituve signs". They are created either pure conventionaly or this convention is based on public tradition, particularly when it comes to abstract objects. It is clear that the term "substituve signs" was a little unfortunately picked out, since all signs exist substituvely in the place of any object in communication acts. These signs correspond with the "artificial signs with a derived expression" in the general sign typology given by SCHAFF(see Figure 3). Here "artificial" means the respective signs are deliberately created to communicate. Consequently the substituve signs in the cartographic communication were designed by way of transmission of spatial information by the cartographers.

We divide these signs once more into two groups, i.e. symbols and icons.

SYMBOLS

The cartographical terminology in view of term "symbol" is quite splitted. In the sense of the sign typology given by SCHAFF[14] the following relation between a symbol and the object represented by it is decively important.

- Symbol is a material sign(it can be seen) and the object represented by it is a abstract term.

- The representation is based on a public convention, which is to be known in order to be understood.

- This conventional representation is determined by the sensuous imagination (in substance allegorical, metaphorical, mythological) of the abstract object[14].

These traits do not need to have a further explanation. In many countries pigeon for peace, balance for justice, cross for christianity etc. can be given as examples.

Similar abstract terms are rarely representation subjects of the cartography. Therefore it should not be further discussed. Detailed information might be seen in [14] and [17].

ICONS

Since there are gradual differences between icons in view of their representation way they are classified into two subgroups, figure icons and plan icons.

Task of figure icons is to represent objects indicative. The shape derivation of figure icons is not strength and immediately determined by respective map projection and by the map scale. The building of figure icons occurs under consideration of the visible or functional traits of the represented object. The shape of figure icon could be purely geometrical. Particularly the form of figure icons is greatly depending on the human abstraction process. The realized corresponding between the object and the look of its sign is called "iconization". In view of that we must avoid to speak from "similarity". There can be similarity only between functionaly resembling objects. Each figure icon has, depending on the grade of the abstraction process by cartographers, different iconization grade. Therefore if the abstraction grade is high, we talk about geometrical signs(icons) and if the iconazitaion grade is high, we talk about speaking signs.

In contrast to plan icons the real size of the objects could not be concluded from the size of signs by using the map scale. When it comes to a thematical quantitative information, the cartographer needs another scale, called figure scale beside the actual map scale. There is not any fixed relation between two scales. Under consideration of the daily usage of the term "plan", plan icons represent existings material or existing fictious nature object locational plan true in according to the map scale and pursuant to graphical possibilities.

For example a point sign for a highest point of a mountain, a line sign for a shore and forest boundaries are plan icons.

The most important difference is that planimetric appearance of plan icons is determined only by the respective cartographic projection and the map scale. Therefore the cartographer has only one possibility to place the plan icons on the map sheet. That means the plan icons can not be varied with orientation. For the placement of the figure icons on the map sheet we have more scope, nevertheles within certain neigbourhood. From the mentioned properties of plan icons it is to be derived that plan icons for linear objects inform inevitably (automatically) about orientation, course and length, plan icons for the areal objects inform about size of area, covering form and orientation in the nature of respective objects. It is clear that the accuracy of information gets less if the map scale becomes smaller(generalization affect).

CONCLUSION

It has already begun for approximately thirty years that maps have been investigates as a communication tool for transmission of information on the spatial reality. On those investigations the new research disciplines help the cartographers to discover the traits of different maps and the map sign system. The semiotic as a general theory of signs is one of them.

In this paper it was attempted to ascertain how the map signs accomplish their task to transmit spatial information from cartographers to map users. It was furthermore a purpose to develop a unequivocal typology for map signs. In order to realize it, they were classified under consideration of a existing semiotical sign typology of SCHAFF[14].

The further advantage of this typology consist in that it is quite a disjunctive sign classification.

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Map expression, map semiotics, map language

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1. Introduction

Since about 25 years the theoretical side of cartography has been intensively developing. We also say, that in cartography, compared to the past, theoretical thinking has intensified. This development manifests itself, beside other (for instance: increase of the technical level, introduction of automation, etc.) in an origin of new theories or theoretical conceptions. I think that this is not a question of "new cartography" any more, emphasized by quotation marks as much as it is a fact of existence, that substantially differs from the prevailingly empiric system of knowledge of map, that was up to now also called cartography.

Maybe someone nostalgically sigh: "Where are those good times, where is that good old cartography that preferred map making to speculations!?" Today are not less maps made, but there is more thinking and more theoretical consideration around them.

Result of higher intensity of cartographic theoretical thinking is the existence of several theoretical conceptions not only on some cartographic procedures, but also on map generally. These conceptions are in some parts of cartography more, in others less distinct. Thus for instance, majority of cartographers know well the conception of the map as a vehicle of informations, as a communication means. Also conceptions of map as a graphic demonstration, as a picture-sign model, eventually as a mathematical-cartographical model, conception of a map as system, etc. are known. In these conceptions many new concepts (terms) were created, even a kind of invasion of new terminology in cartography was mentioned. We are also witnesses of abundant use of older or up to now widely used terms that gain a new content - according to the need of the conception in question. Consequence of their unduly use, that can be hardly avoidable within the frame of discussion (oral or written), is the origin of inadequate, non-equivalent synonymity and as a consequence - chaos in comprehension that can be well compared to the famous language confusion of Babylon moved into our internal cartographic tower.

Confused and unclear is seen also the relation between the terms: map semiotics, map language and map expression by many cartographers. Let me devote them a little attention.

2. Map semiotics

Preconditions of the origin of this term created J.BERTIN in 1967 [2] in his "graphic semiology". His application of the system of graphic variables in the expression of various characters of mapped objects and phenomena can be called the first variant of the comprehension of the map semiotics.

The second variant of comprehension of map semiotics can be recognized in the article of Prof. U.FREITAG in 1971 [3] who believes that cartographic semiotics (his expression) consists of cartographic syntactics, cartographic semantics and cartographic pragmatics. The first part (syntactics) deals with the construction and arrangement of the cartographic signs and rules of their formation and transformation. The second part (semantics) deals with the relations between the cartographic signs and objects of mapping (exactly: their meanings). The third part (pragmatics) deals with the relations between the cartographic means of expression and people i.e. creators and users of maps. This comprehension must be seen in the context of the period when it originated. We know very well that this was the period of a strong onset of the theory (conception) of cartographic communication or communication of cartographic information, that in the present moment is (opinion may differ) in the stage of fading, stagnation, extinction, as it overgrew or it is still overgrowing into other conceptions. Complete comprehension of cartographic or map semiotics cannot be just "passed" without necessary changes, from one conception to another. Result might be similar to the attempt to plant pineapples in a rocky slope where there are suitable conditions for growing grapes (and other cultures) but not for pineapples. Besides, in the course of 70-ties other - sigmatic aspect in semiotics - appeared, and we have to decide what should be done with it and where, i.e. classify it as a sub-problem into semantics or as an individual fourth part of the cartographic or map semiotics. Or quite a new approach to the problem will be necessary.

Thus the third way of comprehension of map semiotics originated, that only partially pertains to semiotics - the linguistic one.

Note:

Also here the opinions may differ. Some people may think that linguistics is only partially semiotic science, others that it can be completely included into semiotics - as a matter or fact it does not desert the definition of semiotics: it too is a science of signs and like human spech, a sign system. Yes, it certainly is, but it is a very independent discipline.

3. From semiotics to linguistics

Classical semiotic view of the map, based on syntactic, semantic, pragmatic and let us add, also sigmaic aspect, after my opinion is being exhausted and semiotics ceased to be sufficiently inspirative for the development of cognition. Much less than it seemed at the beginning. As soon as the researchers run into an obstacle, they investigate two possibilities: either they follow the selected direction, and find themselves in a situation comparable to that of a ram knocking his head against a wall (hoping to open the shortest way across the obstacle) or they try to reach the aim by a new road that may mean a roundabout, delay and risk to run into new obstacles. Much depends then of te mentality (sometimes also of financial menas). In this concise way it is possible to explain also the origin of new conceptions in cartography - without previous repudiation (extinction) of the existing ones.

Why have the cartographers turned to linguistics with hope? I think it is also because the semiotics, as presented by Ch.S.Peirce and Ch.W.Morris, was elaborated by them only on the level of its theoretical base. Also all their followers understand semiotics as a general (generalized) theory of signs and sign system that with its general character is not an applied science. To be able to use the knowledge of basic research more "comfortably" and more efficiently in applied sciences, according to our experience, they require certain preparation, they need certain pre-application phase of its transformation. Those who understand cartograpy as applied technical science will necessarily meet with this difficulty. Utilization of the knowledge of one science in another is not on application level, it is on theoretical level, there is also need of some kind of interface, some area of interdisciplinary knowledge. It is just the system that is solved by such interdisciplines like semiodidactics, ethnosemiotics, biosemiotics, linguosemiotics, etc., and that might mean that also cartosemiotics can most probably have a similar destiny. But it is deduction, in certain sense extrapolation, that can, but does not have to occur. Nevertheless, in any case also cartosemiotics struggles with similar kind of problems. To avoid them in this case means to try what happens if we look at the map from aspect of the language.

The second reason in favour of the trying the language aspect is in some place more in other less evident character of sign systems as the supplementary ones to the natural language. All sign systems that are used by man, the mankind, are a would be substitute of the natural language in the situation where the natural language (in spite of its considerable universality) is insufficient or impractical for the expression of the content of thinking. It occurs in music, painting - in many other human activities in chemistry, physics, mathematics, formal logic, even in traffic (road) signalization. Why should a map be an exception? If it were more advantageous to write words and sentences in a map (or notes or mathematical formulae), map as an a typical sign form of statement on spatially distributed objects, phenomena or their characteristics i.e. a map as we all well know, does not need to exist. But as it exists, its sign system - real or potential - must be examined from the broadest possible aspect, eventually several aspects.

4. Map language

At first in cartography several symbolic metaphoric concepts, like for instance map alphabet, map grammar existed, but by the end of the 60-ties term "cartographic language" appeared explained by A.KOLÁČNÝ [4] as a system of map signs and rules of their usage. As he considered this assertain comprehensible to all, he did not even attempt to explain it or analyze it in detail.

It was a Georgian A.F.ASLANIKASHVILI, who in 1967 event. 1974 [1] introduced the term "language of map" and explained it as an artificial one, formalized, object language of cartography as a specific sign system consisting of great number of signs (he distinguished 10 groups of signs) and of principles and methods of operation of these signs.

L.RATAJSKI [9], a well known Polish cartographer imagined the map language as its grammar i.e. as a system of morphology and syntax of map signs. He distinguished 15 classes of the "letters" of cartographic alphabet. I suppose that these opinions of Aslanikashvili and Ratajski are generally sufficiently known.

A.A.LYUTYY [5] from Russia, suggests that the "language of map" consists of two sub-languages out of which one treats the spatial determination and the second the content determination of the mapped objects and phenomena. He distinguished also the third sub-language - language of names that is identical to the natural language.

In the years 1980-1990 L.NEBESKÝ and B.PALEK [6,7] from the Charles's University in Prague, inspired besides semiotics also by the theory of graphs, tried to explain the "language of map" (or "map semiosis") as a system of longitudinal,transversal and neutral fibres.

A.WOLODTSCHENKO [12,13] from Germany pays attention to the map as a system of pixels as syntactic and semantic units. He elaborated their hierarchy and made attempt at their matrix representation and computerized processing.

H.SCHLICHTMANN [10,11] from Canada views the map expression as a "map symbolism", discerning the problems concerning the classes and characters of the map signs and the problem of composition of these signs into the "text" by means of local and supra-local syntax.

Finally it was also me, who tried to explain the map language [8], while I distinguished four language (or lnguistic) levels: map signics, map morphography, map syntax and map stylistics.

Each of these, at least eight images (excuse me if I omitted someone) is, as a matter of fact, an unidentical explanation, of the term "map language". A single homogeneous conception of map language does not exist yet. With a little bit of effort though, it might originate, if there were a possibility (opportunity and willingness) of some kind of consensus. So far a conception of map language as a sum of several opinions, that are united only as far as the direction, orientation and the aspect of map examination are concerned.

5. Map expression

Should the map semiotics, as a research trend, theoretical conception really exhaust itself, and should also the language conception of map run into similar troubles, there exist solutions either in map investigation as some kind of expression or in the investigation of quite different, other aspect - for example from that of model. That should not be anything new, as matter of fact, "cartographic modelling has been existing since quite a long time".

In comparison with map semiotics or map language, the map epression is a wider term. While its conception does not exist it is (theoretically) a shallow concept, that only superficially denotes certain area of cognition we know very little about. So far we can give content to the concept by understanding it separately eiter as a map semiotics, or as a map language, or also in a whole - both areas together.

But this concept has also a content reserve for more displayed conception of map that might make use of all suitable analogies common to many ways of man´s expression not only through graphics but also by means of natural language. It is confirmed also by a thinking experiment that we made with delinguization of the language conception of map. Result is the possibility of development of new, wider - expressivistic map conception.

6. Summary

Thanks to intense development of theoretical thinking in cartography various theoretical conceptions originated in the last twenty years. To avoid incorrect interpretations and misunderstanding it is important to distinguish the origin and particularly the contents of the news concepts. Unclear is seen by many cartographers also the relation between the terms:map expression,map semiotics and map language.

Map expression. If expression is understood as any (word, musical, graphical, etc.) manifestation of an idea (concept, significance, message, etc.) than map expression must be understood as a spatial reflection of something by means of sign system of map (map language). This consideration leads us to the conclusion, that the concept "map expression" is inevitably broader than the concept "map language". This concept (map expression) has a content reserve for more displayed conception of map. So far we can give content to the concept by understanding it separately either as a map semiotics, or also as a map semiotics and map language - both areas together.

Map semiotics. It is an area of knowledge in the contact level of semiotics and cartography. We distinguish at least three ways of understanding the map semiotics: (1) based on Bertin's understanding of graphic semiotics of map, (2) based on classical understanding of semiotics, but distinguishing besides syntactics, semantics and pragmatics also sigmatics of the map (map sign, set of map sign) and (3) based upon the language conception of map expressing, that is (may be) structurally organized in different way from semiotics. This consideration hints that "map semiotics" is a narrower concept that the "map expression" but broader than "map language".

Map language. Natural language is a system of expressive sign media of certain community serving as a tool of thinking and means of communication and accumulation of knowledge. In our opinion the map language as a map way of thinking and communication supplements the natural language in the area of thinking and communication on space, relations and properties of various objects and phenomena in this space. Map language is a new concept in cartography and its content is only constituing itself. We know several conceptions of map language but neither of them exactly defines it, moreover these conception often contradict each other even in the denomination of this phenomenon. It is desirable to accelerate the research of the map language and make the international discussion more efficient.

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Spatial information systems and the perception of map series on screens

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Introduction

Users of spatial information systems work with screen maps. They use them in large numbers and, individually, just for a short time to explore spatial problems step by step. With that, the map user has to process a lot of short-duration information. Maps generated within information systems often do not support the map user towards this end, which is regarded as a new perception and interpretation situation. The paper specifies some basic requirements for the construction and design of screen maps with regard to the use of map series.

1 Traditional Map Interpretation and the New Situation

There is a difference between maps generated within information systems and traditional maps. Maps generated within information systems represent results of numerical computation, geometrical overlay, graphical aggregation, etc. as a base for further information processing and hence for further maps. Thus, one map contains information which will be processed: recomputed and/or linked with other information in another map. Maps of such a series are increasingly not produced as printed maps. They are more and more generated as screen maps and they are, therefore, graphically present only temporarily.

In contrast to the use of traditional maps, the user of spatial information systems is exposed to a new map perception and map interpretation situation. Computations as executed by information systems are opposite to interpretation processes in traditional maps. Estimation and measurement of map information, or visual comparison of maps are information processes performed by the map user. The results of computations from information systems are achieved by the system and not by the user. So on the one hand, the user of information systems has to comprehend the generation of computed information. On the other hand, he has to remember the previous map information in the following maps related to further information processing. This means that remembering and comprehending information derived from information systems depends on, what is presented by the system and what is perceived by the user of the system. In the following, map series regarded as typical map information of spatial information systems are described concerning aspects of presentation and aspects of perception.

2 Presentation and Perception of Map Series on Screens

For optimizing the new perception and interpretation situation as mentioned above, an approach to a special user environment is needed, which integrates the information required by the map user as a knowledge base and which controls the presentation of maps and map series. The present cartographic perception and interpretation research on the one side (BOLLMANN 1981, BOARD 1984, EASTMAN 1985, VANECEK 1992) and the conceptual and technological development of spatial information systems and their components on the other side (DiBIASE 1992, DORLING 1992) provide a framework for differentiating and examining parameters of presentation and parameters of perception for this approach.

2.1 Aspects of Presentation

The present hard- and software of spatial information systems allows the variation of numerous presentation aspects, which should be formalized by way of quantifying parameters. First the optical media of presentation, such as maps, pictures, video sequences, texts and statistics, can be varied with reference to the mode of presentation on the screen, for example sequential or parallel processing of different media. Secondly the type of maps within a map series vary with reference to the type and the amount of information and with reference to the level of information. At this point, only some aspects of the presentation of maps and map series will be discussed.

Besides the sequential mode of presentation, modern information systems work with parallel data processing and parallel presentation of maps on screens. X-WINDOWS and MS-WINDOWS are examples of basical software products for this. They enable to present several maps or other optical media simultaneously in a different size side by side or overlapping. Each screen window with each map can be controlled independently and can be presented for a variable duration. Map information from one of the first maps within a map series (out of a total of e.g. five or six maps) can be shown again on an additional window. Like this, information systems could support the map user to remember the eventually lost information of one of the first maps.

Maps within a map series generated by information systems differ in the type of map, such as topographic base map and various types of thematic maps. Moreover they differ in the level and the amount of information displayed. Nominal-, ordinal-, ratio- and interval-scaled information can be represented in a different amount, complexity and scale and in different numbers of map layers. Then the amount and the level of information can be transformed into less information or additional information and a lower or higher level of information by processes of selection or aggregation and processes of level transformation for example. This means that map information, which was not displayed comprehensively and simply enough, can be presented in another map of a map series in a more understandable way. Like this, information systems could support the map user to comprehend the question behind computed information.

The condition for the use of these variables in information systems orientated towards the map user is the formalization of these and other aspects of presentation as parameters of an user environment for the presentation and interpretation of map series.

2.2 Aspects of Perception

The present range of spatial data and spatial problems makes high demands on an information system user's and with that on a map user's perception. It is not yet possible to generate maps, which are understandable for everybody and even not yet possible to generate these maps automatically. Besides, the time for comprehending map information within a map series derived from information systems is limited and we do not yet know exactly, what happens with the spatial information of the maps from a perceptual point of view during this limited time. It is therefore necessary not only to focus on elementary map perception and higher-order geographical questions. To optimize the new perception and interpretation situation while using map series on screens we need to focus also on practicable user operations. This should be based on the contemporary perceptual and cognitive knowledge on working with maps and computers. Here, only some aspects of geographical questions and user operations supporting the processing of geographical questions will be discussed.

The processing of higher-order geographical questions is described as a basic requirement for the work with spatial information systems and maps (BOLLMANN 1981, BOARD 1984, NYERGES 1991). According to that, geographical questions can be differentiated with regard to questions determined by geometrical attributes and questions determined by substantial attributes of spatial objects. For the process of map interpretation geographical questions can be structured with regard to perceptual input and output parameters of the target orientation, the target conditions and the target values (Fig. 1).

User operations integrated in common user environments of information systems generally include facilities for the user to orientate geographical questions processed within a map series for his own targets. Besides any optional operations with data, such as the selection and the aggregation of data or the choice of processing and representation methods, it is possible for the user to determine the duration of the presentation of maps within a map series. Moreover the presentation of a map can be repeated. Furthermore spatial information required by the user could be indicated or/and accentuated by special graphical symbols.

3 Empirical Tests on the Perception of Map Series on Screens

Based on the structure of geographical questions and map interpretation as mentioned above (see 2.2 and Fig. 1) students of cartography at the University of Trier/Germany carried out some empirical tests on selected perceptual problems connected with the interpretation of screen-displayed map series. These tests were realized as tests for a single test

Target Orientation of Geographical Questions	Target Conditions of Geographical Questions	Target Values of Geographical Questions
Parameters as Perceptual Input	Parameters and Parameter Values as Perceptual Input	Parameter Values as Perceptual Output
Location and Distribution - of objects - of amounts of objects... Characteristics of Objects - substantial value - geometric dimension... Relations of Objects - distance between objects - type of distribution... Characteristics of Object Relations - less or more important - less or more characteristic...	Comparison to foreknowledge - typical shape of known object - typical spatial structure... Foregoing Orientation - predominant symbols - typical graphic structure... Syntactical Orientation - discrimination of symbols - classification of symbols... Strategy of Interpretation - strategy of reading "through" - search for symbol type...	State and Position of Objects - individual value - absolute position... Relations of Objects - minimum/maximum value - relative position... State and Situation of Amounts of Objects - medium value - medium size... Relations of Amounts of Objects - level of information - shape of amounts of objects (regions)...

Fig. 1: Relation of Geographical Questions and Map Interpretation

person tested by specially prepared screen-displayed map series. The single map of a map series was displayed for a certain time. After the presentation the test person has had to answer to questions also displayed on the screen. Before, the attention of the test person was directed to the object of the question followed by the presentation. For each examined hypothesis a total of 20 students of cartography were tested. The tests realized for the training of students in visual information processing are methodically regarded as pre-tests for further empirical studies on processes of map interpretation concerning the screen-based work with spatial information systems. Here, three examples of altogether eight realized tests will be shortly described.

The first example is based on geographical questions related to the location and characteristics of "phenomena": "What is the phenomenon there and how much of the phenomenon is there?" (BOARD 1984, NYERGES 1991). These questions are regarded as target orientation of geographical questions. The target of the questions in the first exemplary test was to search for objects with certain characteristics, as for instance soil-scientific sampling points within the range of the maximum value of soil pollution with cadmium. In a first map of altogether four maps presented as a map series the test person had to localize the objects characterized by this target value with mouse and screen locator. In a second, third and fourth map further characteristics of the same objects were displayed. These characteristics were related to the characteristic displayed in the first map, as for instance soil pollution with lead. In each of these maps the test person had to indicate the remembered position of objects characterized by the maximum value in the first map. The hypothesis for this test was, that the test person will not remember the target value in the following maps (Fig. 2). The results of the test significantly show a decrease of certainty to remember the position of objects with the maximum value in further maps of a map series.

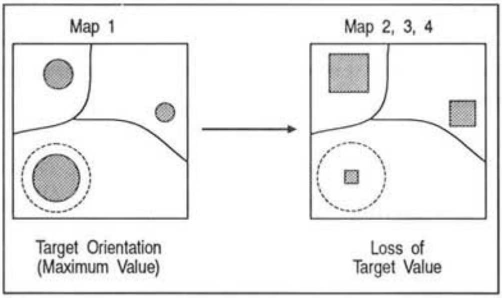

Fig. 2: Loss of Non-remembered Characteristics of Objects in Map Series

The second example is based on geographical questions related to distribution and pattern of "phenomena": "Is there a regularity in the phenomenon distribution and what kind of distribution does the phenomenon make?" (BOARD 1984, NYERGES 1991). Here, the target of the question in the test was to find out and to remember characteristics of amounts of objects. In the first map of the map series the test person had to indicate the shape of an amount of specially distributed objects, such as an agglomeration of industrial emission sites along an arterial road. In a second, third and fourth map containing other amounts of objects distributed differently the test person had to remember the agglomeration displayed in the first map and should draw its typical linear shape with the mouse on the screen. The hypothesis for this test was, that the test person will not remember the target value "linear shape", if totally different kinds of distribution follow in the next maps (Fig. 3). The results of the test do not verify the hypothesis. As well-known in perceptual research it is easy to remember the outer shape of a region if it is simple and distinct, as for instance a linear or compact shape (ANDERSON 1989).

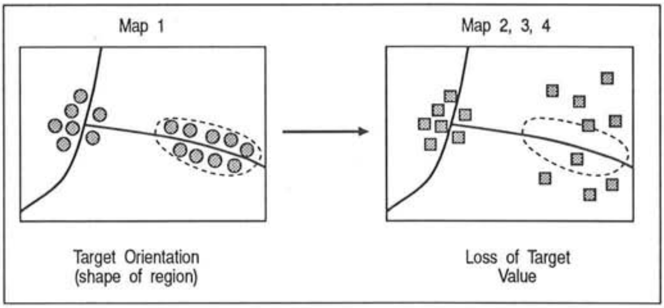

Fig. 3: Loss of Non-remembered Shape of a Region in Map Series

The third example is based on the target conditions of geographical questions, as for instance the previous knowledge or foreknowledge respectively we use to recognize objects or relations of objects during map interpretation (BOLLMANN 1981, EASTMAN 1985). Here, the target of the question in the test was to search for objects with certain characteristics, such as objects within the range of the maximum value as described in the first example. Additionally all maps of this map series were containing a well-known object with its typical outer shape. It was the typical shape of the city of Berlin. In the first map of the map series the test person had to localize the objects mentioned above with mouse and screen locator. In the second, third and fourth map further characteristics of the same objects were displayed. In each of these maps the test person had to indicate the remembered position of objects characterized by the maximum value of the first map. The hypothesis for this test was, that the ability of the test person to remember the information will depend on the distance to the well-known object (Fig. 4). For the evaluation of the results circular zones of distances surrounding the well-known object were defined. The results show, that any characteristic of an object can be better remembered, if it is close to a well-known object.

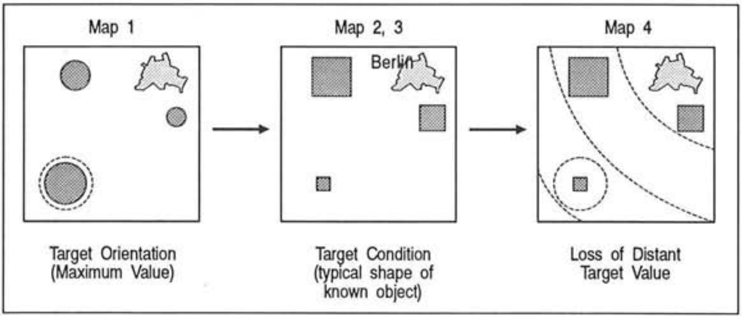

Fig. 4: Rank of Characteristic Object for Non-remembered Information in Map Series

4 Optimization of Map Series on Screens

Generally it seems to be, that the certainty to remember previous map information within a map series can decrease with the number of presented maps and probably decreases with the duration available to interpretate the map also. The questions and the results of the tests show, that there is a difference between the target orientation of geographical questions and actually perceived target values of geographical questions. This difference depends on the one hand on the target conditions of geographical questions (see 2.2, Fig. 1) and on the other hand generally on aspects of presentation (see 2.1).

The interpretation of map series on screens of spatial information systems could be optimized, if aspects of presentation would be orientated on this difference. Besides the orientation of data structures, symbols and symbol patterns and their explanation in special legends for screen map series an interactive user environment for this purpose should allow as well the orientation of so-called additional graphics towards the new perception and interpretation situation connected with the use of spatial information systems. At this point, only some examples for the application of additional graphics will be described.

Additional graphics can be described as symbols, which are independent from real cartographic representation. They are applicated by the map user on request of an user environment in case of the presentation of map series on screens, if as described above target values of geographical questions are "in danger of being forgotten" (BOARD 1984). Their purpose is to save these target values by pointing out the target orientation and target conditions of geographical questions graphically.

Characteristics of objects, as for instance a maximum value of soil pollution data could be indicated by a leading colour or other special graphics like blinking symbols extending through all maps of a map series.

Characteristic shapes, as for instance the linear or compact shape of a region could be accentuated by bordering the region of interest. The additional border for a region could support the map user to comprehend the linkage of the information of shape and further characteristics of that region displayed in following maps of a map series.

Characteristic objects, as for instance a well-known city with its typical outer shape, could be displayed within a network of "equidistant" basical map objects in each map of a map series. A single characteristic object could be additionally accentuated, if target values of geographical questions are located close to them.

Summary

The user of maps derived from information processing in spatial information systems is exposed to a new perception and interpretation situation. Map series on screens, regarded as the typical map information of today, often do not support the map user in order to remember previous map information in the following maps of a map series. Based on aspects of presentation and perception of map series on screens three empirical tests are described. The concept and the results of the tests lead to some basic

requirements for the design of an user environment, which allows to optimize the perception and interpretation of map series on screens.

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Mapping in the future: the needs of young children

J.M. Anderson (Montreal, CDN)

Abstract

Young children, that is children under the age of seven years, are capable of both understanding the concept of a map and working with maps. The development of cartographic literacy among young children, is an area which has largely been neglected by the mapping community, and needs to be addressed. This paper focuses on some of the questions to be considered if the cartographic community is to be actively involved in improving the level of cartographic education for the young child.

Introduction

Current trends in computer technology have led to an increasing number of predictions that many of the maps produced in the future will be generated not by cartographers but by individuals with little or no cartographic training. Such a prospect is raising concerns regarding the nature, quality and usefulness of the maps which will be produced. One possible solution to the dilemma consists of the provision of an effective basic level of cartographic education to all. The focus of this paper is on the mapping needs of the next generation of map users and producers - those who are children under seven years of age.

Attitudes to children's mapping needs vary according to nationality. As my empirical research has been with Canadian students, included is a brief overview of the context in which their map instruction is provided. Mapping, in elementary education in both Canada and the United States of America, usually occupies a very small 'skills' component of the Social Studies Programme - that is an integrated programme which includes history, geography, economic, sociology, anthropology and psychology. Unlike countries with a national curriculum (e.g., United Kingdom), each Canadian province and territory is responsible for producing its own pedagogical guide which is then implemented by the schools in the various school boards. Characteristically, the majority of social studies texts which are produced to support the curriculum provide: a) little introduction to mapping concepts and map use prior to Grade Three (nine years of age); b) large numbers of 'picture maps' of unfamiliar and fictitious places, (e.g., a farm, a treasure island); and c) only the vaguest of guidelines to teachers for map skills instruction and mapping activities. Pedagogically, the priority given to mapping is low. This in turn fosters an attitude of neglect or only a cursory consideration of mapping modules, an attitude which is reinforced when there are time constraints or the teacher lacks experience with the subject matter.

The three M's: map skills instruction, maps and map activities:

Young children mapping needs can be summed up simply as the three M's: map skills instruction; maps; and meaningful map use activities. The complexities involved in providing these, however, are enormous. Individually, each of the three M's is important, but their paths intertwine. Realistically, cartographers can only produce appropriate maps for a young audience if they are aware of their abilities and the contextual requirements of educators. Unfortunately, however, there appears to have been little interaction between the cartographers, who theoretically should be responsible for the "maps," and the "educators" in whose domain map skills instruction and map use fall.

Map skills instruction

The onus of neglecting young children as a cartographic audience cannot be directed at the discipline of cartography. Educators' beliefs that young children were not capable of meaningful work with maps stem from their adoption of the research findings of developmental psychologists, particularly the work of Jean Piaget[11], related to the child's concept of space. The young child's capabilities to deal with maps remains controversial[6]. However, there is a growing body of opinion that children's spatial abilities have been underestimated[7]. Studies show that children, in many cultures, prior to any formal schooling understand maps[9] and are already capable of many mapping activities, for example, identifying features on aerial photographs[4], locating features on a large scale map and using a map of a short route[12]. There are also an increasing number of empirical studies that show young pre-school and school children in the early elementary grades, are capable of working with maps[2], completing location and navigation tasks[8], and interpreting quantitative values on thematic maps[13].

My research, conducted over the last eight years in Montreal with 300 anglophone, urban, Kindergarten and Grade One students (five to seven years of age), found that children of this age were indeed capable of understanding and using both large and small scale, abstract, planimetrical maps. With instruction, Kindergarten students demonstrated that they were very capable of working with many of the basic concepts associated with mapping: scale; orthogonal perspective; abstract map symbolization; the nature and use of a map key; and location utilising a simple alpha-numeric grid reference system[1]. It should be noted, however, that although Grade One students comprehend that a map is a representation of reality at a reduced scale, they experience difficulty with linear distance unless it can be measured in units they can directly relate to, e.g., number of hands/steps, the time it takes to walk a particular distance.

Young children are fascinated by maps. This mental attitude coupled with the increasing evidence of their ability to work with maps presents an excellent environment for laying the groundwork of map literacy. But, what should this groundwork comprise? What is meaningful mapping instruction? My findings suggest that in order to provide instruction which the children benefit from, attention should be paid to the following three items. First, the basic map concepts mentioned previously need to be introduced by concrete rather than abstract activities using materials to which the students can directly relate; second, that the instruction should actively involve both teacher and peer interaction; and, third, the instruction should focus on activities that initially concentrate on both the creation of maps by means other than drawing and the use of maps.

Conventionally, mapping activities for young children stress drawing maps rather than map use. In my research with both Kindergarten and Grade One students I observed that although young children are capable of understanding the concept of vertical perspective, their ability to incorporate this perspective into their maps proves to be both difficult and frustrating. This is hardly surprising since all their early introduction to graphic communication, and their own graphic expression, is through drawings with a horizontal perspective.

Maps for the young child

Irrespective of how educators introduce mapping to young children, maps (one of the three M's) are indispensable. Since there is an absence of maps directed at this age level, the primary contribution of the profession to improving cartographic literacy would appear to be the conceptualization, design and production of maps suitable for the young child. However, prior to the producing such maps one has to identify what constitutes suitable map materials.

Young children understand maps primarily as an aid to wayfinding, but they do not perceive themselves as map users. Such perceptions suggest that the young child would benefit from positive early mapping activities in an environment in which he/she can directly interact. Where the teacher wants to work with an environment which is familiar to children, the map material is black and white air photography, if available. Rarely obtainable are large scale maps of an individual school and its immediate environment (e.g., 1:2000). In reality, the "mapping materials" used in the early grades are the globe and 'pictorial maps' of fictitious environments in their Social Studies texts. Arguments for the use of picture maps focus on their ease of comprehension and the inability of students, who cannot read, to work with a map key. In a map context there is little published research which examines either the effectiveness of a young child's use of pictorial symbols or the role of these symbols in facilitating or hindering the understanding of an abstract map. Currently, therefore, the criteria directing the choice of pictorial map symbolization for young children reflects the personal beliefs of the map designer (graphic artist or designers), rather than its successful interpretation by the young child.

There is an absence of abstract, planimetric maps for young children although this is the form of map to which most children are exposed. If cartographers decide to redress this situation, attention must be paid to the design and use of the map key (map legend). Kindergarten students, who cannot read, can work with an abstract map if it is accompanied by a map key in which the abstract symbol is equated with a picture rather than a word[1]. However, the choice of appropriate pictures, by the map designer, can be illusive. One alternative approach to this problem is to involve the prospective map user in the design of these pictorial map legend symbols. In a recent study that I conducted, 50 Grade One students were asked to draw pictures of features which would appear on a map of their school. For each feature five drawings, representing a cross section of those produced, were redrawn and 150 students asked to identify which one they thought most reminded them of the feature. This exercise produced some interesting representations and preliminary results. Consider for example the two map features, a schoolyard and a parking lot. Figures 1 and 2 represent black and white renditions of the drawings shown to the students. In Figure 1 the options two and three accounted for 88 percent of preferences. In Figure 2, options two and three proved to be the most popular choice as they were selected by 62 percent of the students. Perhaps the most striking characteristic of these preferences is that these are a combination of two perspectives, the vertical and horizontal. I believe few cartographers would consider incorporating such graphics into a map key designed for a young map user. The students' preference for drawings with two perspectives, however, should not be taken as universally applicable. A vertical perspective was preferred for a road, while pictures with a horizontal perspective were chosen for both familiar (e.g., grass) and unfamiliar items (e.g., an electricity pylon). Since such graphics allow students with a limited reading facility to work meaningfully with large scale abstract maps, should the use of such unconventional graphics be dismissed lightly?

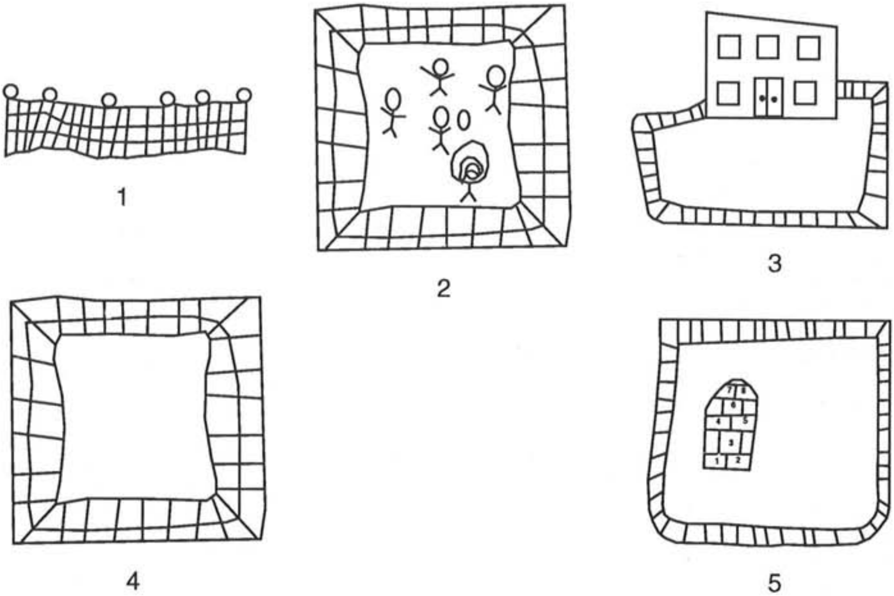
The presence of a map key helps to convey the message that a map is not a picture but a graphic representation employing a symbolic code system which can deciphered. The role of the map legend and its utility to elementary children has received little attention. Any cursory study of maps prepared for early primary grades frequently reveals map symbols at one scale on the map, and a generally smaller scale representation in the legend. For adults such a representation is untenable as it can lead to errors in map interpretation. Does such a size discrepancy between map and map key symbol representation matter to the elementary child? This question generates inquiry about the employment of basic symbol characteristics. For a child, what characterizes a particular map symbol? Is it the symbols, colour, shape, size, the feature's function or some combination of these? Do the symbol characteristics employed vary according to the medium of presentation: paper versus a computer screen? For young children the parameter of size for certain symbols may be secondary to shape or colour combinations. The use of colour in children's maps is another largely unexplored area. Most cartographers would probably assign similar, conventional hues to a map, for example, green for trees and grass, whether it was designed for children or adults. These, however, may bear little correlation to those a child would select.

For young children, the act of using a map in a familiar environment provides a positive experience which reinforces their comprehension of basic map concepts, demonstrates the value of a map as a spatial tool, and promotes the perception that they can be successful map users. However, such maps exist only if created by innovative teachers. Although there are more questions than answers to designing maps for the young child, to develop cartographic literacy one course of action could be for members of the cartographic community to investigate ways to facilitate the creation of large scale school maps, directly or indirectly, through interaction with teachers.

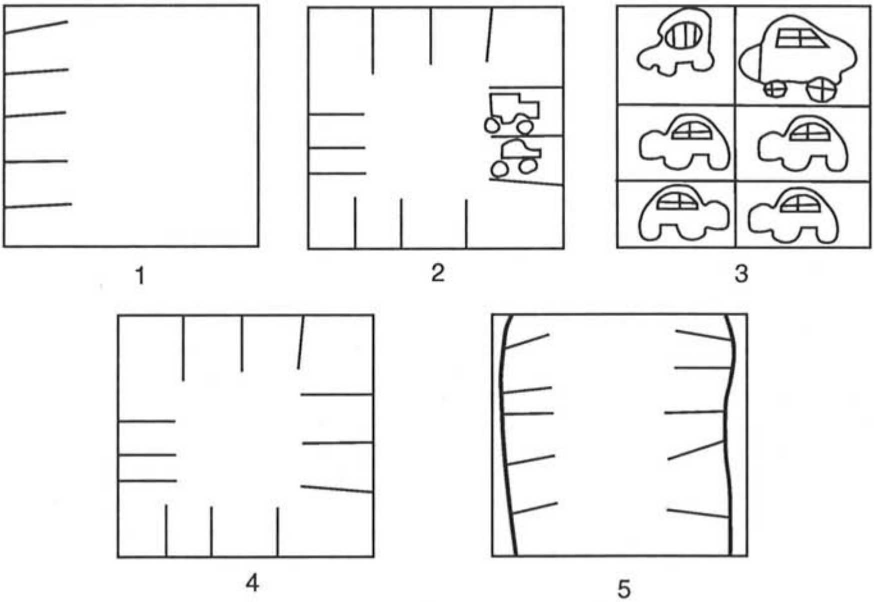
Mapping Activities

If one takes as given that appropriate maps exist and that students have received pertinent map skills instruction, what constitutes the use of maps in a meaningful context? Young children

Figure 1 Schoolyard by Grade One (redrawn)



Fi gure 2 Parking Lot by Grade One (redrawn)



need to be able to relate directly to the environment depicted on a map otherwise the value and usefulness of maps remains elusive. Activities should be positive and build upon what students are already able to perform prior to formal instruction. This could include activities such as creating and using models, pictorial, and plan view maps in a logically ordered nested hierarchy of familiar environments, e.g., classroom, school, and area surrounding the school environment. The context of increasingly complex environments (classroom/a room at home, the street and the community) now constitutes the approach adopted in social studies texts. However, actual representations of a real environment are unavailable unless made by the teacher or produced as a result of some higher grade activity, e.g., the construction of a scale model as a mathematics exercise.

I am unaware of any maps skills software that is used with children under seven in a school environment. Given the recent explosion in computer-based education for preschool and young children in reading, writing and mathematics, it is only a matter of time, however, before such mapping software is created, despite the fact that mapping for young children is in its infancy. The advantages of young children's use of the computer are well documented, e.g., students can work at their own pace and receive immediate feedback. Although I believe there is a role for computer-based map skills instruction, for young children, such instruction is only desirable after the basic mapping concepts have been introduced using concrete activities related to a directly observable environment. However, such concern may prove to be theoretical rather than practical when faced with the realities of the unavailability of large scale maps of the school and its immediate surroundings, and the teachers' unfamiliarity with mapping concepts and time constraints.

Meaningful map activities should not be restricted to the school. They can also be carried out in public locations, for example, a museum, shopping centre, or park. Few public places, however, have maps which are available and are at a height accessible for use by the young child.

Cartographic community involvement

With concern about graphic literacy growing in many countries, and the likelihood of more maps being generated using personal computer software what should be the nature of involvement and contribution to the cartographic community in the three M's.?

We need to become more involved. As a profession we need to promote the nature and value of maps to members of the general public. As cartographers we appreciate the value and utility of maps, but fail to recognize that this sentiment is not widely shared. In an article by Dr. Petchenick[10], reference was made to a survey conducted among a 200 average adults from the cities of Washington and Chicago. Half of the respondents stated that they would prefer to use verbal directions to maps to help them drive to a novel destination. The capacity of parents to act as both positive or negative role models for mapping activities, from an early age, should not be underestimated[9]. If the level of cartographic literacy is to be improved in the elementary school, the profession needs to work with educators, curriculum developers and psychologists. Cartographers need to become actively involved in research. With only a few exceptions, namely Dr. Petchenick[3] and Dr. Castner[5], few cartographers have made more than a brief perusal of mapping for elementary children. The challenges facing such research are enormous as the needs of children both at the elementary and high school level require investigation. Members of the cartographic community have devoted much time to mapping for the blind. Now a similar effort is needed for a larger population - young children. As a profession we need to provide not only maps but also become visible in the provision of map skills education for teacher training. As professionals we should conduct research, and work with organizations and individual teachers, young students in school and other environments to provide **early, positive personal** experiences with maps.

Conclusion

Current trends in computer technology are leading to an increasing number of predictions that many of the maps produced in the future will be generated not by cartographers but by individuals with little or no cartographic training. This prospect is raising concerns regarding the nature, quality and usefulness of the maps which will be produced. Although one resolution of this dilemma may be the development of cartographic expert systems, another solution consists of the provision of a basic level of cartographic education for all.

I believe that the next generation of map producers and users - our current generation of young children, are capable of becoming cartographically literate if they receive appropriate map skills instruction and work with well designed maps in meaningful mapping activities. As cartographers we pride ourselves in our expertise in the graphic communication of spatial information. If we are not complacent, such expertise provides us with a unique opportunity to become more actively involved with **all** aspects of the three M's of the elementary school map user: maps, map skills instruction and mapping activities thus ensuring the future integrity of mapping. As cartographers, we have the opportunity to play a significant role in changing the perceptions of many elementary school children that, 'maps are something that big people use.'

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Session 16

Atlas Cartography II

Chairman:
F. Ormeling, Universiteit van Utrecht (Utrecht, NL)

Present state of the national atlas of Spain. Future projects

F. Aranaz (Madrid, E)

During my previous presentations, Budapest (1989) and Bournemouth (1991) I had the opportunity to tell you about the project of the NATIONAL ATLAS OF SPAIN.

The first time, in Budapest, the project was just about that: a project. A project that we looked at with hope, after its approval by the Spanish Cabinet of Ministers the 13th of June of 1986, and the later assignment to the General Direction of the National Geographical Institute by a royal decree of 13th of January, 1987.

Initially it was structured in 48 sections with an extent of 640 pages that were supposed to be edited in loose sheets, assembled in booklets, in a volume and finally in compact discs still pending to be defined. A project that was approached with a different philosophy to the one used in other National Atlas production.

The second time, Bournemouth, two years later we had the opportunity to present the two first published booklets of the NATIONAL ATLAS OF SPAIN: "Environmental Matters" and "Oceanic facets" all together 56 pages containing 48 pages with general information, that made approximately, a 7,5% of the initial plan.

And now in Köln, two years later, it is a pleasure for me to have the opportunity to tell you about the actual situation of the NATIONAL ATLAS OF SPAIN.

At the end of January of 1993 we had finished with 22 subjects edited in 18 booklets a total of 644 pages containing 572 pages with general information, that means a 100% of the total plan.

As you can see in hardly six years we have reached our aims as regards the number of published pages, but we still obviously have around a 50% of the subjects included in the original plan.

Following with this parameters of work we foresee that the NATIONAL ATLAS OF SPAIN will contain a total amount of 1400-1500 pages or even more as we have left some subjects on the way.

I am not going to talk now about sizes, types, scales....you have probably heard of it in past occasions. I just want to present short information of the finished work and the present work as well as some brief remarks about were we want to go in the future. I will be assisted with graphic illustrations so you can see first hand this work.

NATIONAL ATLAS OF SPAIN

GROUP	TITLE	ORDER OF EDITION	PAGES
2	GENERAL REFERENCE MAPS	12	4 + 36
3a	CARTOGRAPHIC REFERENCES		
3b	TABLES OF GEOGRAPHICAL DATA	17	4 + 44
3c	LANDSCAPE	6	4 + 40
5	GEOLOGY		
6	RELIEF	16	4 + 32
7	SOILS	9	4 + 16
8	GEOPHYSICS	11	4 + 24
9	CLIMATOLOGY	7	4 + 28
10	HYDROLOGY	18	4 + 32
11	BIOGEOGRAPHY, FLORA AND FAUNA		
12	NATIONAL PARKS	13	4 + 28
13	OCEANIC FACETS	2	4 + 28
14	DEMOGRAPHIC INFORMATION	5	4 + 52
14b	DEMOGRAPHIC POTENTIAL	10	4 + 36
17	AGRICULTURE, CATTLE AND FISHING	14	4 + 44
18	ENERGY	4	4 + 24
19	INDUSTRY. GENERAL INFORMATION		
20	INDUSTRY. SECTORIAL INFORMATION	3	4 + 40
31	FINANCES AND PUBLIC TREASURY	15	4 + 20
39	ENVIRONMENTAL MATTERS	1	4 + 20
41	TERRITORIAL INFORMATION: OTHER INSTITUTIONS APART FROM I.G.N.	8	4 + 28
	TOTAL.............................		72 +572

NOTE
All the presentation will be realised with slides.

GROUP 2 - GENERAL REFERENCE MAPS

Date of edition: July 1992

Number of pages: 4 + 36

Contents:
- The representation of Spain through the History of Cartography
- Satellite Spatial Image of Spain, Europe and The World
- Political and Physical maps of Spain, Europe and World maps
- Astronomical information and Map of the sky in Spain

Cartographical proceedings:
Reproduction of diferent types of old maps as illustration to the text. Usual treatment for political and physical maps with two exceptions: Worldmap with azimuthal equidistant projection centered in Madrid. Map representing the sky of the North Hemisphere extended up to 30° south declination; that brings the posibility to see almost any part of the sky at any time of the year.
Includes 44 maps:
- 8 maps double size (World, Europe and Spain)
- 1 map of the sky + 4 complementary maps
- 1 map with scale 1: 9 M
- 27 reproductions of old maps
- 3 satellite images (World, Europe and Spain)

Plus:
- 13 pages of general text
- 7 complementary texts
- 7 photographs

Comments:
Political and Physical maps of Europe with scale 1: 10 M and 1: 6 M contains the Canary Islands on their real position in relation to the Iberian Peninsula.

GROUP 3a - CARTOGRAPHIC REFERENCES
GROUP 3b - TABLES OF GEOGRAPHICAL DATA

Date of edition: April 1992

Number of pages: 4 + 44

Contents:
It has been included a reproduction of the spanish territory with scale 1: 500.000 specifically made for this group.
It also includes a list of selected geographical data from several fields: geographical positions, hydrology, orography, National Parks, population...

Cartographical Proceedings:
Contains a new map with scale 1: 500.000 based on the type World 1404, but with some special characteristics as indicated in the general text
Includes 16 maps:
- 12 maps double page with scale 1: 500.000

- 1 map single page with scale 1: 500.000
- 1 map with scale 1: 4.5 M
- 2 reproduction of maps with scale 1: 500.000

Plus:

- 2 pages of general text
- 12 pages with tables of geographical data

Coments:
The new map has been prepared to be printed in eight inks

GROUP 3c - LANDSCAPE

Date of edition: January 1992

Number of pages: 4 + 40

Contents:

- Information about a selection of landscapes that are repre sentative of the spanish land.
- Big cities: Madrid, Barcelona
- Evolution of certain towns that have experienced a big change of population for natural reasons, migration, turism, change of crops, etc

Cartographical proceedings:
The selection of landscapes is represented with a group of maps with scale 1: 200.000 of each area: topographical map, geological map and land use map, also vertical and oblique air-photographs and a satellite photograph.
In order to study the change of urban and rural structures we have resorted to old plans and old air-photograps to make a comparison with the actual ones
Includes 101 maps:

- 1 map with scale 1: 6,5 M
- 13 fragments from topographic maps with scale 1: 200.000
- 13 fragments from geological maps with scale 1:200.000
- 13 fragments from land-use maps with scale 1: 200.000
- 5 reproductions from MTN with scale 1: 50.000
- 42 air-photographs
- 13 satellite orthophotomaps with scale 1: 100.000 and 1 with scale 1: 50.000

Plus:

- 19 photographs
- 40 explanative texts and seven pages of general text
- 1 statistics graph
- 26 graphics
- 1 reproduction of an old map

Comments:
For the study of the urban and rural landscape it has been used black and white old photographs from 1945-1965. They have all been treated with colour in order to make easier the comparison with the recentt ones

GROUP 5 - GEOLOGY
GROUP 6 - RELIEF

Date of edition: February 1993

Number of pages: 4 + 32

Contents:
The group 5 includes information about geology, tectonic features including the representation of a geological profile.
The group 6 begins with a representation of the relief emphasizing on the information obtained through satellite. Following with brief information about geomorphology to conclude with information on digital models of the territory and the various posibilities they bring.

Cartographical proceedings:
Includes traditional geological, tectonic, geomorphological... maps, with the new technology derived from the use of digital models of relief.
It has also been included a specific study of the relief representation from an historic perspective, without forgetting the different types used in conventional representation (contour lines, shadows, inks, etc.) and the contributions of the spatial information
Includes 27 maps:
- 5 maps double page with scale 1: 2 M
- 1 double page with geological profiles
- 2 maps with scale 1: 4.5 M
- 4 maps with scale 1: 500.000
- 8 reproductions of old maps
- 1 geomorphological map with scale 1: 50.000
- 1 topographical map with scale 1: 25.000
- 1 guide map
- 4 digital models

Plus:
- 11 photographs
- 2 graphs
- 10 pages of general text

GROUP 7 - SOILS

Date of edition: May 1992

Number of pages: 4 + 16

Contents:
Spanish soils, characteristics and types

Cartographical proceedings:
- Reduced use of maps due to the nature of the subject.
- Completed with other material such as graphs, statistic-graphs, photographs and drawings that allow a deeper knowledge of the subject.

Includes 6 maps:
- 1 map double page with scale 1: 2 M
- 5 maps with scale 1: 9 M

Plus:

- 47 photographs
- 1 air-photograph
- 5 graphs
- 12 drawings
- 5 pages of general text

Comments:
The map of soils has allowed to clasify 113 different types of land.
We have also included the "rañas" special feature of some areas of Spain

GROUP 8 - GEOPHYSICS

Date of edition: September 1992

Number of pages: 4 + 24

Contents:
Composition of the Earth, dynamics and evolution; gravity; geomagnetism; seismology; volcanism and a sinthesis of other related matters

Cartographical proceedings:
Combination of maps and other material such as photographs, drawings and graphs that make easier the comprehension and interpretation of this phenomenology, usually not well known by the general public
Includes 34 maps:
- 2 maps double page with scale 1: 2 M
- 1 map double page with scale 1: 3.5 M
- 2 maps with scale 1: 1 M (Canary Islands)
- 12 maps with scale 1: 4.5 M
- 1 map scale 1: 6.5 M
- 2 maps with scale 1: 9 M
- 1 map with scale 1: 11 M
- 2 maps with scale 1: 13 M
- 6 maps with detailed areas
- 5 World maps with different scales

Plus:
- 8 photographs
- 1 graph
- 15 drawings
- 5 explanative texts and six and a half pages of general text

Comments:
In some maps has been necessary to extent the information towards the west of the Peninsula in order to show in all its scope the phenomenology as result of the fault Azores - Gibraltar.

GROUP 9 - CLIMATOLOGY

Date of edition: March 1992

Number of pages: 4 + 28

Contents:
- Thematic clasification
- Precipitation
- Hydrometheors (snowfall, hail, fog and storm)
- Temperatures
- Relative humidity
- Sunshine
- Solar radiation
- Seasonal Pressures and winds
- Usual meteorological maps

Cartographical proceedings:
Traditional processing with isopleths and or coropleths
Includes 111 maps:
- 13 maps with scale 1: 4,5 M
- 6 maps with scale 1: 6,5 M
- 80 maps with scale 1: 9 M
- 12 synoptic maps with scale 1: 46 M

Plus:
- 40 photographs
- 14 explanative texts plus 4 pages of general text
- 41 graphs

Coments:
The work for this group was made with Macintosh to evaluate this procedure

GROUP 10 - HYDROLOGY

Date of edition: March 1992

Number of pages: 4 + 36

Contents:
Information about the water in the World and Spain, administrative organization of the water in Spain; climatic factors; hydraulic infrastructure; water resources; gauging and regime of the spanish rivers; humid areas and glaciers; ground water; characteristics and quality of the water; dams, reservoirs and reservoir water; hydraulic engineering; historic floods; demands, uses and balances.

Cartographical proceedings:
Use of conventional cartographic patterns. The historic data have required a specific treatment; Nowadays we still count with hydraulic systems from the roman period (II Century). The floods can also be foreseen as they happen during specific meteorologic situations.
Includes 41 maps:
- 2 maps with scale 1: 2 M
- 4 maps with scale 1: 4.5 M
- 20 maps with scale 1: 6.5 M
- 7 maps with scale 1: 9 M
- 8 maps with other scales

Plus:
- 34 explanative texts and 5 pages of general text
- 14 photographs
- 23 data tables

- 52 graphs
- 2 drawings

GROUP 11 - BIOGEOGRAPHY, FLORA AND FAUNA
GROUP 12 - NATURAL AREAS

Date of edition: October 1992

Number of pages: 4 + 28

Contents:
The group 11 includes information about:
- Climatic and biogeographic regions
- Forest areas and its species
- Areas of special significance for: wild flora, endemic flora, protected species of fauna and species threatned with extintion

The group 12 presents information about Special Protected Areas and National Parks

Cartographical proceedings:
- Graphic information completed with explainative texts for better comprehension of the subject
- The representation of the trees and fauna threatned with extintion has been completed with photographs of the same and literal information
- Similar process for National Parks and its flora, fauna and landscape

Includes: 61 maps:
- 6 maps with scale 1: 4,5 M
- 4 maps with scale 1: 6,5 M
- 28 maps with scale 1: 9 M
- 12 maps with scale 1: 11 M
- 1 map with scale 1: 2,5 M (Canary Islands)
- 10 maps with scale 1: 200.000

Plus:
- 132 photographs
- 28 explanative texts plus 5 pages of general text
- 10 graphs
- 10 Tables of data on National Parks

GROUP 13 - OCEANIC FACETS

Date of edition: May 1991

Number of pages: 4 + 28

Contents:
- Bathymetric information and submarine relief
- Sea floor sediments and geomorphology
- Sea biology of the diferent areas of the spanish coast
- Coastal features
- Tidal movements
- Temperature and salinity of the sea water
- Waves: height and direction
- Sea currents

Cartographical proceedings:
The variety of the content has demanded the use of several types of representation and individual solutions for each case, always emphasizing the representation of the sea against the land. Use of traditional symbols.
All this information is included in 63 maps:
- 1 map with scale 1: 20 M
- 2 double page with scale: 1: 2.5 M
- 1 double page with scale: 1: 2 M
- 1 double page with scale: 1: 1.5 M (in parts)
- 2 maps with scale 1: 1 M (Canary Islands)
- 3 maps with scale 1: 4.5 M
- 10 maps with scale 1: 4.5 M (different areas)
- 4 maps with scale 1: 6.5 M (different areas)
- 9 maps with scale 1: 1.8 M (different areas)
- 16 maps with scale 1: 9 M

Plus:
- 23 photographs
- 13 graphs
- 38 drawings
- 9 explanative text and four pages of general text

Comments:
The treatment of this group includes some special points:
- The relief maps (Iberian Peninsula and Canary Islands) have been made by water colour, with a later colour selection
- The map of Gibraltar Strait made at our Institution after an Spain-Morocco agreement as a previous study for a posible connection (bridge or tunnel) between Europe and Africa.

GROUP 14 - DEMOGRAPHIC INFORMATION

Date of edition: January 1992

Number of pages: 4 + 52

Contents:
Information about the Spanish population since the XVI century up to the present time containing: consecutive census; population piramids; population variations by provinces, evolution of the urban population, population by municipal districts; civil state, rate of unmarried state; population ageing; population mobility; births; marriage; deaths; interior migrations; spanish residents abroad and foreingn residents in Spain; populational baricenters and statistic graphs

Cartographical proceedings:
The extent, diversity and complexity of the problematic included in this group has made us adopt different solutions for each map or groups of maps.

The representation of census has been made by spheres (as the volume is proportional to the r3) due to the big differences between cities with 4 million of inhabitants and others with 40.000.
The use of census from such a long period of time has made us use extent scales of 11 segments for the representation of the

provincial population density; ten segments for the birth rate; eight segments for death rate ...

On the other hand, in order to represent extent series of data pointing out the variations in births, marriage, and death during the period 1860-1985 the cuantitative paramethers have been represented by "transparent" figures (hexagons, circles, squares), in order to show the colour of the back.

The maps that refer to population mobility have been resolved with arrow diagrams (red for emigration and green for inmigration).
Includes 167 maps:
- 6 maps double page with scale 1: 2 M
- 4 maps with scale 1: 4.5 M
- 11 maps with scale 1: 6.5 M
- 142 maps with scale 1: 9 M
- 1 world map double page 1: 60 M
- 1 world map with scale 1: 120 M
- 2 maps with other scales

Plus:
- 7 photographs
- 12 data tables
- 79 statistic graphs
- 19 complementary text and five pages of general text

Comments:
One of the most important works is the ellaboration, specificly for the National Atlas of Spain, of two maps about spanish population obtained from the end of XVI century census (Censo de los millones) and from the end of XVIII century census (Relaciones de Intendentes), both of them adapted to the territorial structure of that time.

GROUP 14 b - DEMOGRAPHIC POTENTIALS

Date of edition: June 1992

Number of pages: 4 + 32

Contents:
Information about demographic potentials and balanced variations of the spanish municipalities. Dynamic of population of spanish towns with more than 5.000 inhabitants in four periods.

Cartographical proceedings:
The information concerning the population potentials has been developed on a geographical criss-cross pattern of 5 km side, for the years 1970, 1981, 1986 and 1991 using eight segments of colour. Similar treatment but with 12 segments (positive range and negative range) has been used for the study of population variations. The population dynamic has been represented by

spheres for the values of population and a colour matrix (3 X 3)
Includes 11 maps double page with scale 1: 2 M
Plus:
- 1 photograph
- 5 graphics
- 8 pages of general text

Comments:
This work has been done specificly for the National Atlas of Spain by a team from the Human Geography Department of the University of Zaragoza

GROUP 17 - AGRICULTURE, CATTLE AND FISHING

Date of edition: November 1992

Number of pages: 4 + 44

Contents:
In relation to agriculture it has been included information about characteristics of the climate, agricultural soils, land use structure (full owners, cropland, pastureland, smallholding...) and population working in this sector. We also go over agricultural products (vegetables, forage, horticulture, flower growing, cereals, olives and vineyard, fruit trees and industrial crops). Data on the production means are also included.
The information about cattle has been clasified by types: (sheeps, cows, goats, pigs, poultries, horses and donkeys, bees, rabbits...)
The production means are also included.
Information about forest presents the different forest types and various types of hunting and river fishing.
The information about deep sea fishing includes data on the fleet, fishing grounds and volume of catch.

Cartographical proceedings:
The heterogeneus subject has required various cartographical proceedings with the common purpose of giving information, not only quantitative but qualitative. To this effect we have included temporal series of data with the purpose of showing the evolution of certain sectors in regresion of the Western World.
Includes 165 maps:
- 12 maps with scale 1: 4.5 M
- 4 maps with scale 1: 6.5 M
- 146 maps with scale 1: 9 M
- 1 map with scale 1: 19.5 M
- 2 maps with several scales (1: 18 M and 1: 60 M)

Plus:
- 22 photographs
- 12 explanative texts and 4 pages of general text
- 18 tables with data
- 78 graphs

GROUP 18 ENERGY

Date of edition: October 1991

Number of pages: 4 + 24

Contents:
Information on the main energetic centers, energy raw materials; the stages of production, ellaboration, distribution and consume. Electric energy, socioeconomic data on primary and final energy. Spanish energetic balance.

Cartographical proceedings:
Includes 36 maps:
- 2 double pages with scale 1: 2 M
- 11 maps with scale 1: 4.5 M
- 23 maps with scale 1: 9 M

Plus:
- 11 photographs
- 1 explanative text and 3 pages of general text
- 49 graphs
- 1 table

Comments:
The large amount of stastistic information has been displayed with graphs and diagrams.

GROUP 19 - INDUSTRY. GENERAL INFORMATION
GROUP 20 - INDUSTRY. SECTORIAL INFORMATION

Date of edition: September 1991

Number of pages: 4 + 40

Contents:
The first part includes information about general aspects of the spanish industry such as: gross production, industrial establishments; investments, new industry; working population, unemployed; industrial accidents...
The second part includes data related specificly to work and added value in the twentythree sectors that constitute the spanish industry as defined by the Ministry of Industry.

Cartographical proceedings:
Since the subject requires the use of similar representations we have chosen a very simple form where fast comparisons in the total value and the porcentage variations within a close past can be easily made.
Includes 55 maps:
- 2 double pages with scale 1: 2 M
- 51 maps with scale 1: 4.5 M
- 1 map with scale 1: 6.5 M
- 1 map with scale 1: 10 M

Plus:
- 23 pictures
- 4 graphs
- 8 pages of general text

Comments:
Due to the new territorial division of Spain in Autonomic Comunities the information refers to the same so we do not count with statistic information refered to the provinces.
On the other hand the final data we counted with to make this work in most of the cases came up to 1985.

GROUP 31 - FINANCES AND PUBLIC TREASURY

Date of edition: December 1992

Number of pages: 4 + 20

Contents:
Includes information about the economic potential levels, added value in its different meanings. Gross national product, family income, expenses by family and per capita; National, regional and local budgets, financial system, insurance system, stock market etc..

Cartographic proceedings:
The representation of the large number of statistic data has been done on carthographic bases and other times with diagrams. In other occasions in order to compair consecutive periods we have used concentric round figures.
Includes 45 maps:
- 3 maps with scale 1: 4.5 M
- 13 maps with scale 1: 6.5 M
- 29 maps with scale 1: 9 M

Plus:
- 7 photographs
- 2 tables of data
- 51 diagrams
- 11 explanative texts and two pages of general text

Comments:
During the realization of this group we have considered the possibility of including here the business sector in all its scope; having decided finally to dedicate to it an independent group.

GROUP 39 - ENVIRONMENTAL MATTERS

Date of edition: April 1991

Number of pages: 4 + 20

Contents:
- Forest fires
- Erosion
- Air pollution
- River and coastal pollution
- Aquifer systems and the quality of ground water
- Wide spread pollution (fertilizers, insecticides, cattle and organic wastes)

- Mineral, industrial, and solid urban wastes
- Landscape degradation and special protected areas
- Preventive actions: air quality control and public water control

Cartographical proceedings:
Conventional proceedings with maps of isoplets and/or coroplets, use of traditional symbology. All this information is included in 26 maps:
- 3 maps with scale 1: 2.000.000 double page
- 5 maps with scale 1: 4.500.000
- 8 maps with scale 1: 6.500.000
- 2 maps with scale 1: 13.000.000

Plus:
- 17 photographs
- 12 explanative texts plus 4 pages of general text
- 6 graphics
- 8 drawings
- 1 statistic graph

Comments:
First booklet of the Atlas that was published

GROUP 41 - TERRITORIAL INFORMATION:
OTHER INSTITUTIONS APART FROM THE NATIONAL GEOGRAPHIC INSTITUTE

Date of edition: May 1992

Number of pages: 4 + 28

Contents:
Information about the available carthography in Spain, made by different national institutions apart from the National Geographical Institute.
Includes the national cartography produced by the military services (Army, Navy and Air Force) and geological, agronomical, nautical, aeronautical and cadastral carthography.

Cartographical proceedings:
We have tried to give a general information about the above mentioned cartography made in Spain available to the general public.
Includes 59 maps:
- 17 guide maps with different scales
- 36 fragments of maps with different scales
- 1 double page with scale 1: 2 M
- 5 cadastral maps with different characteristics

Plus:
- 5 photographs
- 1 drawing
- 21 complementary text and four pages of general text

At this moment we are starting, as we planned, working on the project of the electronical atlas.Considering the different possibilities (CD-ROM, MAC, PC, VIDEODISK, ...) we are now analizing advantages, disadvantages and cost of each one.

Now a reasonable possibility (with certain reservations) would be the videodisk. We are thinking on two prodution and development levels in function of the characteristics of the users .

The version A for Public Institutions, universities, bussiness field, ... could be realised with disks of great capacity and size to tactile screen.

The version B for general public, schools, small libraries, ... could be realized with videotape for T.V. screen or alternatively with diskettes of small size for compatible P.C.

During the first nine months of the present year we hope to prepare some prototypes with different private companies that will enable us to evaluate them. Only then we will take a final decision.

There is another point I do not want to miss today. At this moment has appeared in Spain an unussual interest for carthography and for Atlas in general, I do not know wether it is related to the edition of the National Atlas of Spain.

I want to point a fact: Right now the two main spanish journals with the largest edition "ABC" and "EL PAiS" are publishing in their weekend newspaper two Atlas in booklets.

The first one, "ABC" is publishing "The great road Atlas of Spain and Portugal", that also includes many maps of cities, around 200 pages plus other 25 pages with toponimical index.

The second one "EL PAIS" has published the last months a similar Atlas with 215 pages plus 70 pages with toponimical index. Now they have started again to publish a second Atlas, foreseen to be publish along 25 weekends with 300 pages more or less containing thematic information about Spain and the 17 Autonomic Comunities.

We think this initiatives will contribute to create a cartographic sense in our country.

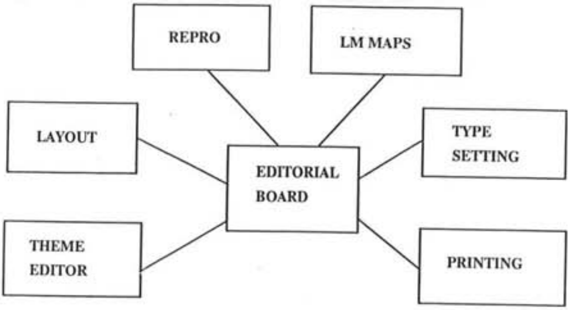
The national atlas of Sweden – an atlas produced by new technology

U. Arnberg, M. Elg, M. Syrén (Stockholm, S)

A map is a generalized picture of reality. Today, this reality, changing at an increasing rate, is presented in maps that are produced with a fast digital technology. Increasing numbers of maps made by a heterogeneous group of people offer us better opportunities to disseminate information, but the risk that the maps will contain errors is also increasing. On the other hand, the new technology makes the errors easier to correct. Nonetheless, they must be discovered before publication and before the damage caused by incorrect information has occurred. The new technology enables us to make increased amounts of knowledge available, which is one of the obvious objectives of a national atlas.

The National Atlas of Sweden is a series of 17 volumes. The volumes are of large format with hard covers and each with about 150 pages. The present series does not include loose maps. Each volume deals with a specific theme, such as agriculture, geology, population or environment. The decision to finance a new National Atlas of Sweden (the first, Atlas över Sverige, was published in 1953-1971) was made by the Swedish Parliament in 1987. The first volume was published in 1990, and the seventeenth and final volume is planned for 1996. The volumes are printed in editions of about 15 000 in Swedish and 5 000 in English.

The Editorial Board, with three editors for production of the volumes, is located in Stockholm. Preparation of material for each volume is the responsibility of a theme editor, generally a specialist in the subject being treated, who is chosen on the basis of his thematic knowledge. The theme editors are recruited from different national authorities or university departments throughout Sweden.



When an approved manuscript is submitted to the Editorial Board in Stockholm, the first task is to prepare a layout which is done in the traditional way by a professional layout firm in Stockholm. The subsequent production of books is done mainly by three producers. The text is produced by a type-setter in Gothenburg, photographs and drawings are reproduced by a firm in Luleå, and maps and diagrammes are produced digitally by LM Maps in Kiruna. The decentralized production, with contacts throughout Sweden, places great demands on the Editorial Board in Stockholm, where all the material is processed, to coordinate the work. In the present context, we will concentrate on the digital production of the maps.

Production of maps with digital technology was one of the conditions placed when funds were made available by Government. Perhaps even without this condition, it is the self-evident method to use in large-scale production of maps today. Digital technology is only a new tool in map production, but this new method nonetheless places new requirements on the different stages of production, from manuscript to the printed page. Already when processing the data, consideration must be taken to how the subsequent production will be done in order to ensure that data are, for example, stored correctly. Layout work, for example, depends on the choice of colours available. When the different components of the maps are to be specified, we must have knowledge of the advantages and disadvantages inherent in the technology. In the final processing of the map, our knowledge of the technique must enable us to utilize the computer in the best manner. In addition, the computer must be developed continuously, which might lead to the work programme being changed and perhaps also the demands placed on the original manuscript. The new knowledge related to production must be disseminated also to the people preparing the data. This

important flow of knowledge, related to the different parts of the production process, places great demands on the people concerned but is a condition for good results at reasonable expense.

We will now look at the production of one of the maps in the largest scale we use for the National Atlas, 1:1.25 million. This is the map of arable land and meadow found in the volume on Agriculture. It was entirely compiled by the computer technology available at that time. Here, there are no features of the manual handling necessary for production of the corresponding map in the previous national atlas, Atlas över Sverige. That map was based on data from 1944.

The manuscript for the map was submitted as digital data on contents, and discussions were made on how the final map should be prepared. Data were collected from Statistics Sweden. The data consisted of figures on the arable area in hectares per parish in 1989 and the area of meadow in hectares per parish in 1988. The northern limit for winter cereals was digitalized manually using a transparency placed over the map, and digital data for the highest shoreline were supplied by the Geological Survey of Sweden.

The symbols used were discussed and an initial proposal made on data such as borders and hydrography to be included, how symbols for the theme should be designed, which colours should be used, the place-names that should be included on the map, and how the layout of lists of symbols should be done.

The computer operator placed out the symbols automatically on the open land according to an earlier map and then created the rest of the contents in the map. Place-names were entered. Proofs were submitted in the form of an iris - a coloured picture. Corrections were made, and when we were satisfied with the result, the final films were prepared. The Editorial Board were largely responsible for the cartographic design, and were also able to be present during printing.

What are the advantages and disadvantages of the computer technology we use in the different stages of production? How does it change the work of the cartographer? And who is, in fact, the cartographer?

THE MANUSCRIPT

The advantages of digital data, here collected from public statistics, are clear. The data available are reliable in that they do not need re-typing or reading which may lead to errors. It is easy to transfer data between the different stages of production. In addition, the data are so comprehensive that today it would be impossible in Sweden, both with regard to time and economy, to handle them manually. Errors in the data might have occurred before they were digitalized, or while they were being entered. There is a trend to believe that it is unnecessary for people with knowledge of the subject to assess the correctness of digital data. In addition, data must usually be grouped into classes and, when done automatically, this might result in an incorrect picture. The expert and the cartographer must establish limits for the classes.

Despite many people in Sweden believing that we have statistics on everything, there are many situations where this is not the case. On this map, for example, we were unable to show comparable figures on arable land and meadow for the same year, and in addition, whereas all agricultural businesses were reported in 1988, only businesses with at least 2.1 hectares of arable land were listed in 1989. Naturally, the situation was not better earlier (probably the opposite) but today we may easily find ourselves omitting information simply because it is not available in a database, other approaches are often not considered. In addition, it may be impractical and time-consuming to combine analogue and digital data in the same production.

ARABLE LAND AND MEADOW

0 50 km

1:1 250 000

- Arable land, each square represents 100 hectares
- Meadow, each square represents 100 hectares
- Bedrock and other open areas
- Forest land
- Marsh
- Area above tree-line
- Umeå — Urban area, more than 50,000 inhabitants
- Kiruna — Urban area, 20,000–49,999 inhabitants
- Lerum — Urban area, 10,000–19,999 inhabitants
- County boundary
- Highest shoreline
- Northern limit of winter cereals

SYMBOLS

On this map, we chose to symbolize 100 hectares of arable land and meadow with a square, sized 0.8 x 0.8 mm. The choice of symbol was inspired by the older map in Atlas över Sverige, but the new map was to be produced by computer technology. Arable land was to be printed in red, meadow in green. A pale yellow colour was to show rocky land and other open land, whereas forest land was indicated by a green-grey colour. In addition, two limits were included: the highest shoreline and the northern limit for growing winter cereals. The colours in the final map are not the same as those in the first proposal. One of the great advantages of computer technology in map production is that the colours can be changed whenever required at a relatively low cost and even during the final phase of production.

THE WORK OF THE COMPUTER OPERATOR

The symbols for the two classes were automatically processed so that the correct number of squares was placed on the open land of the parish. The automatic processing naturally cannot decide whether the open land is in fact arable land. In fact, this symbol does not imply 100 hectares of continuous arable land but is simply a generalization of data. Neither was it possible for the computer operator to decide whether the symbols had been placed at the most suitable spot. However, placing out the ca. 35 000 symbols manually by a knowledgeable person cannot be considered today. In this way, we use the new technology to transfer some of the specialized work to a later phase in the production. Earlier, there had to be no doubt about where the symbols should be placed when preparing the original. Today, the computer does most of the work and we then make the necessary adjustments. Perhaps this can be described as the computer first assisting us to prepare a manuscript with which the author, editor and cartographer can then process further. The computer is inflexible in its approach to work since it only does what it has been instructed to do and, in addition, it is completely without judgement if we consider that judgement is a human characteristic.

What, then, happened to this map? In the first proof, it was essential to check thoroughly and with good geographical knowledge that the symbols had been placed correctly, otherwise they would have to be moved by interactive work. A good example of what might happen can be seen on the southern part of the

Island of Öland, where there is an extensive area of limestone grassland identified on the map as open land but which is definitely not arable land. The symbols had to be moved out along the coastline where the arable land is found.

If we look at the map more closely, we can see that some of the arable squares are not on open land. This is because the degree of generalization of forest land in the final work was chosen so that forest land would not be unnecessarily broken up in order to avoid disturbing the distribution pattern of arable land and meadow. The automatic location of symbols, however, was done with higher resolution towards forest land. The forest land was then generalized but the symbols remained. This was a method enabled by computer technology.

As mentioned above, the colours can be easily changed even at late stages of production. The computer offers us good opportunities to create shades of colour, where each process colour can be changed from 1 per cent to 100 per cent. It may be tempting to use features of a few percentage units in order to achieve a desired shade. However, experience has taught us that this leads to problems at later stages. Even very small variations in conditions when plotting, developing and copying film will have relatively large influences on the low colour percentages. In addition, variations in printing will influence the final result. During printing, it is necessary to consider all illustrations on the sheet. The colours according to the specifications entered on the computer must be exactly the same but may have fairly different shades.

A printer's nightmare?

WHO IS THE CARTOGRAPHER IN PRODUCTION OF MAPS WITH COMPUTERS?

Is it the person who decides what the map will look like and perhaps has made a sketch with pen and paper? Is it the computer operator? Is it the person who reads the proofs? In our project, we have assumed from the start that the responsibility for cartography must be divided between the

Editorial Board, the theme editor and LM Maps, i.e., mainly the computer operator. However, it is difficult for the computer operator, who produces only one or more thematic maps among many without having any review of the contents of the book or specialist knowledge of the subject, to be a good cartographer. Such knowledge is only available at the Editorial Board where the editor has contacts both with the author (subject knowledge) and the computer operator (technology).

In a small country such as Sweden, there are few cartographers with knowledge of small-scale thematic mapping, partly since there is no specific education in this subject. The editors of the National Atlas of Sweden have a background in geography and cartography at university level and experience of the graphics branch. The computer operators at LM Maps mainly have a background in mapping technology. It is necessary to create a common language for what we do together and also to try to understand the conditions under which both sides are working. A map compiled with modern computers must never be of poorer quality than was possible to achieve with traditional technology, and we are convinced that this need not be the case. Computer technology offers us greater opportunities, but nonetheless we are still able to control the computer and, as human-beings, we are the ones assumed to have good judgement. So don't blame the computer if the map is a disaster!

Atlas cartography in Albania

E. Samimi, E. Seferi (Tirana, AL)

"Atlas Cartography in Albania"

Brief History

The land of Albanians, located in the Mediterranean coast, has invited cartographic interest since the ancient times. There exist maps dating back to 200 B.C, which contain illyrian settlements like: Durrachium, Scodrae, Lissus, Bylis, Antigone etc. and the rivers Drilon, Aous, etc.

In the I-II century A.D, Ptolemeu in his work gives the coordinates of 52 inhabited illyrian centres. He makes use of the polar conic projection and pseudoconic one with the Poseidon's measurements for the earth. His atlas was the most accurate of his time.

Later my country was mapped in the Pentigerian Tables. These practical means of war and the use of special signs display even the curves and road lengths. There, appear new aettlemets like: Koplik (Sinna), Ishmi (Pistrum), Peqin (Clodiana), Qukës (Trea, Tabernas), etc., as well as the rivers Hapsuni (Semani), Lindigo (Liqeni i Ohrit), Genesis (Shkumbin) etc.

The arab culture has made its contribution to the Illyro-Albanian mapping through the work of Al-Idriz in 1154. The map orientation is Southern. The inhabited centres are marked with a circle and for the first time Petrela is noticed.

Distinguished authors in the world have devoted their attention to the mapping of Albania. Among such authers are: Reis Merkatar, Gostold, Kontali, Vignola, Komotio etc. In their maps, besides the marginal decorations, there apear new toponyms like: Pogon, Tepelen, Pirespa (Prespa), Mezaiko, (Myzeqe), Opar, Mat (Makio), Kepi i Gjuhëzës, (C. de Languete) etc. Gotaldi distinguished himself for his complete content and the originality of compilation, where we come across Guri i Bardhë, Drivast (Drishti), Zorzi (Shirqi), Arzento (Erzeni). There is also a map of Komotio dating back to 1571. This could be considered as the first operational-topographic map where the system of settlements, arable lands and castles is given.

Further on, maps of Albanian land have been compiled by Orteli, Çelebi, Maziette, Blaeu, Fischer, de Witt, Nolin, Janson, Sanson, etc. Lastly, Koroneli in his atlas. among coloured decorations publishes the maps on Albania. These are the first maps where hydrography is given in blu, vegetation in green and writing in black. They display a rich content and for the first time the capital of Albania, Tirana, appears.

The 19th century witnisses intensified efforts, especially of medium scale (1:300000) and small maps. The Albanian land begins to attract the cartographic interest of I.G.U of Viena and I.G.U of Firenze. Of specil merit is the map by Kiepert at the scale 1:200.000 published in 1870. At this time thematic maps on ethnography, roads, economy and geology are published. Among other authors are: Menke, Kiepert, Spruvel, Baldacci, Han, Gubernati, Bue, Nopca, Saks, Galanti, Ridels, Evans, etc.

In 1870-1912 the Geographic Institute of Viena undertook a basic cartographic work, the result of which was the publication of the map 1:75.000. The maps are polichrome and quite read able.

After the Proclamation of Independence in 1912 the Geographic Institute of Firenze was appointed at the Comission to survey the frontier line (width 2 km) at the scale 1:50.000. This qualitative work was completed by 1922-1925.

A work of great value is also the map of Herbert Lui in 1928 of the scale 1.200.000. His is an operational-topographic map, based on the elipsoid of Basel and on the Gaus-Kryger projection. Until 1960 it has served as basis for many a thematic map. Lastly, in the 1930-ies, the Geographic Institute of Firence, through the photogrametric work based on a new network of triangulation, published a series of maps at the scale 1:50.000. These samples were used during the 2nd World War and after it.

This quick run through the cartographic history of Albanian land, I hope, has given you an insight into it.

I believe that the history of mapping in Albania resembles a landscape which is still to be painted to completion by this end of century. It is our conviction that Albanians have rendered their contribution to these works, but unfortunately it has been overshodowed by the vast knowledge of the foreign specialists and obsured by the haze of time. Research must be taken into the archives and wells of cities like London, Berlin, Viena, Rome, Istambul, Vatican, Venice etc., in order to trace the pioneers of Albanian cartography and picture the complete history of mapping of "das land des Skipetares". Such an undertaking, in collaboration also with the honoured collegues of this meeting, would be most welcome.

50 years "Socialist cartography"

After the 2nd W.W, cartography and geodesy in Albania have never been seen as separate scientific disiplines. Their contribution has come to the fore only when the immediate needs of other spheres of life have called upon, thus aiming to give a "piece-meal" temporary product, so as not to waste the time of the other so-called important branches. The geo-topo-cartographic work has developed by fits and starts, a thing which is contrary to its accurate and meticulous nature. No economic or scientific institution has left a breathing space for its normal development. Programmes, objectives and funds have shrunk according to the "appetite" of the other brouches. So, needless to point out its subordinate, servicing function and a lack of programming of its present and future objectives, which of course are entitled to their role and place in the entirety of our life.

The possibility which cartography gives in dealing with the immediate problems of life and in finding the most national solutions for them, is still brittle in the hands of the specialists of various fields of economy.

First, the need of mapping was imposed by the land measurement. Courses for topographs were conducted by specialists of pre-war education. There, the first cartographic knowledge on cadastral work was imparted.

In the 1950-ies the soviets made the basement and the aerial photographing. Maps of the scale 1:25.000 and smaller ones were published. In the years 1965-1975 these works were carried out again by the Chinese which produced the complete map 1:25.000, maps at a smaller scale and those of the lowland area at the scale 1:10.000. Details on these works are to be found in Rolf Böhme's article: "Inventary of World Topographic Mapping". The cartographic experience of the Albanian specialists has been of the level of the assistant, without ever producing an independent work.

Nevertheless, 50 years has not been a totally insignificant period for our cartography. In the last two decades the wall of indiference towards the benefit of cartography has cracked. Here we'll try to list with a critical eye some of the developments of our cartography:

In the field of topographic cartography there exists a Military Institute of Topography. It takes pride in the above-mentioned topographic maps which cover the whole territory, produces maps (1:10.000) for the inhabited and hilly regions and updates the maps at 1:25.000 and of those at a smaller scale.

In the field of Engineering Cartography, there exist topographic groups in the service of the direct management of the departments of contruction, geology, geophysics, oil, forests, etc. They compile engineering maps (from 1:500 to 1:5000), at small quantity.

In the work of these groups it is interesting to observe a kind of fetishism of the topographic work and the negation of the generalizing process, which they see as a forgery process of the map content. There have also been cases when an experinced specialist has been confronted with the task of compiling a thematic map of his field of study at the scale 1:25.000. He has tried to include there all the situation and the relief of the basis map 1:25.000, holding to the conviction that the new map is "more accurate", "more truthful". When the work is done, he sees that there are too many elements crammed in there, which make the reading of the map difficult. The lack of cartographic training and education is heavily felt.

The field of School Cartography, has witnessed a better progress. Until 1980, 10.000.000 copies with a variety of 400 titles were published. This means 4-5 maps or atlases for each pupil. The thematic range cover the geography and history of the world and of the country itself. Of course, they have been subject to gradual renovation.

In Albania, the idea of the map as a school means has been common and perhaps this folk mentality has gripped the educational department, thus unhappily affecting an effective sponsoring until 1980.

In the field of Thematic Cartography, its theme specialists have considered it as their exlusive domain. they have been jealous of their product and have stoodaloof from cartographic thought. In one occasion, the specialists of the geological map published in 1970 took as their basis the geographic elements of Herbet Luis's publication of 1928. It was e very good map of its own time but not at all fit as a basis for a publication in the 1970-ies. Their fanaticism was carried so far as to imitate the same orthography. In the map of forests, the specialists considered it illegal to mark the inhabited centres with circles, thus leaving a sign of a building instead and so making the reading of the thematic elements very difficult.

These difficulties brought about by the amateur level of knowledge, are known and can be overcome, only that they require 1 or 2 years or a new publication so as to make the specialists conscious of cartography proper.

In the last two decades, interest in thematic maps has grown. Today we have a series of such maps (15-20 titles at a scale 1:200.000 and 1:500.000), for various fields of economy and culture. A work of value is also the Climatic Atlas of Albania with basis maps at 1:500.000.

Nonetheless more efforts are needed on the part of specialists to grasp the well-known idea according to which regional and national studies and research require first a series of thematic maps, and then the novel idea can again be placed in these maps with the view to achieve an optimal and rational planning and use of every investment or of phenomenon under study.

There is also another mentality. Once the specialist has finished the final proof for the map, then he loses all interest in it during the time of cartographic projection, compilation and publication, since this takes a relatively long time and is done through conventional methods. In this context, computerization would be the best way for the salvation of the thematic cartography.

Talking about Cartographic Education, we rejoice at the fact that cartographic lessons are still held in the branches of geodesy and geography of our University. But it is regrettable to point out the lack of lab. equipment even for the conventional cartography and let alone the computerized one. The same situation faces the institutes of the Academy of Sciences and other departments in the ministries. Here the mindset that cartography has a seconday, subordinate role to geography and geodesy has also prevailed. Whereas cartographic generalization is only a forgery.

The scanty possibilities offered by handful of real specialists, lack of quantity and variety of equipment low number of copies have turned the cartographic enterprises into close cycle ones, meaning that every thing was concentrated in one place.

Today there exist two of such enterprises: the Military Topographic Institute for topographic maps and the School Means Enterprise for the school maps. The other institutes preparing thematic works, when faced with the cartographic aspect, have to turn to these two enetrprises.

Designing and compilation of the original is made by hand. The only most sophisticated equipment is the mechanical pantograph.

The projection is calculated and created analitically.

It must be emphasised that the Chair of Geodesy at the University has elaborated its own equivalent pseudoconic projection. More details on this are to be found in the poster of this meeting. Over the projection the abriss blue copy is mounted and the original is drawn; or its elements are given in same ozalit copies.

The technique of scribing the linear elements and masking is that on Statilene material of the Keuffel & Essen firm.

The names and other writings grouped according to size and graphic type are first photo-set and then mounted. The orthographic rules of the Albanian language have been worked out some twenty years ago and are still holding.

Finally, printing is carried out with offset machines with two colours. Their date of production goes back to the fifties.

We judged that it was of interest for the audience to have this quick run through the Albanian Cartography of these last 50 years. It's the first time that Albania comes to this cartographic forum. Hence, we hope to attract the attention and invite the critique of the audience to the problems we face in preparing the thematic school and complex atlases.

Atlas Cartography

It all began in 1960 with the school atlases, the publication of which, though slowly, still continues to this day. Initially, atlases in Albanian language were made in the former Soviet Union. Their content badly matched our school programmes, and moreover, there were serious gaps and misinformation since the Illyrian-Albanian regions were treated according to the slavic point of view. This practice was discontinued after the 1960-ies with the publication of the Primary School Atlas and Atlas of Albania for the high school. Their content was designed and elaborated in accordance to our school programmes based on modern concepts. Their publication with the subseguent updating was carried out annually until 1982, the year when they began to undergo revision.

The Albanian views on history were expressed in cartographic shape in the Atlas of the Albanian History and in that of the National-Liberation War destined for the use in the high schools and University. This far-reaching destination was determined by technic-economic factors. This fusion of two educational levels made possible the minimal number of copies for the off-set printing press.

Their content was the result of the joint work of historians and cartographers. Naturally, the marxist-leninist outlook struck a gloomy note in it. These atlases contain 30-50 maps each and their format in 23 x 32 cm.

The Climatic Atlas of Albania is the only one in the line of thematic atlases. The Academy of Sciences was able to finance it. The specialists of hydrometereology, accustomed to the old maps with the geographic elements laid on transparent sheets or ozalit (in this or that scale), could not accept a unified basis of geographical elements. Finally, there was reached an agreement, according to which the working maps should be of the scale 1:500.000, whereas for publication they should be 1:800.000. The format was 32x46 cm and there were 120 maps all in all.

The needs for planning, direction and management of the economy, the ratioanl use and protection of the environment have highlighted the idea of the valuable contribution of cartography in these directions. The efforts have been materialized in the designing and compilation of some atlases. which we'll try to list as follows:

1. Atlas of Tirana district (Agriculture-Livestock-Forests-Pastures). The designing work was started in 1984 by a group of cartographers and specialists of various fields of agriculture.

Its conceptual frame work contained the ideas that it should:

- be an information system for the agriculutral entirety of Tirana district.
- give a cartographic overview of the situation and dynamics of environment and the farmer's administration and activity upon it.
- give the variety of agricultural technology in the geographical space of the district.
- give the tenor of the development of the main phenomena 15 years ahead.

- attract the user-specialist of the agriculture of the district.

In order to materialize the above-mentioned conceptual framework, a consensus was reached that:

- The basis map was to be at the scale 1:100.000. It should be framed in the atlas with the format 44x45 cm. This scale lends itself to the presentation of small surface units (separate villages), on which statistical data are available. The smaller scales vary up to 1:2.500.000.

- The themes are grouped into 8 subjects: Geographical position, Population, Natural Conditions, Economy, Management, Technology, Forest and Pastures, Future and Prognosis.

The maps on each subject illustrate the situation (inventory maps), the structure and dynamics of the phenomena, the technological feature and the regional planning in space and time. The themes have been displayed in 260 inventory maps on situation, giving instructions for the organization of the work and planning for the future. Two examples may illustrate this.

* The water balance-sheet for the crops. The user is supposed to find there the izolines of the water-norms for the crops and thus administering the irrigation process according to it. The variables for the calculation of this norm are: the efective rain faill, the underground waters and the need of crcps for water. Thus, conclusions can be drawn for an optimal irrigation in the future.

* The ratio active farming population/agricultural soil. According to the data from 1981-1990, calculations have been made on the values of this ratio for the coming 15 years for each inhabited centre. The izolines which show this phenomenon are drawn. Thus one can draw the conclusions where to encourange or discourage this phenomenon cartographically presented. In this way optimal plans for investments can be achieved.

The Atlas tends to be a working tool for the authorities and the agricultural specialists

2. Atlas of Fruit-tres in Albania. It was conceived with the view to being a necessary tool for the fruit-tree specialists, in his work administering them throughout the country. Hence, through maps the atlas gives:

- The natural, economic, demographic conditions which create the background for the development of the fruit-trees in Albania.

- Their dynamics for the coming 15 years.

- The intertwining of the human and natural factors with the material and agro-technic ones which influence the development and grouth of fruit-trees, thus enabling the user to find the most rational way for their administration today and for the planning of tomorrow.

To implement the above-mentioned concept the basis map at the scale 1:500.000 will be contained in an atlas page with the format 39x66 cm. The regional maps vary from 1:100.000 to 1:50.000.

The themes of the Atlas are grouped into seven subject: Geographical pozition (3 maps), Population (12 maps), Natural Conditions (24 maps), Organization (14 maps), Production (15 map), Technology (52 maps), Prognosis (18 maps). The scales of serial maps vary from 1:600.000 to 1:2.000.000.

This Atlas has been sponsored by the Ministry of Food and Agriculture and it has reached the stage of preparation for print in the Military Institute of Topography.

3. Geographic Atlas of Albania. There has never been a unified basis for the geographic elements. Thus, all the cartographic works have been carried out on basis maps chosen at convenience. Therefore

this atlas was conceived to be a unified basis for all the thematic, cartographic works, be they regional or national.

On the basis map (at 1:100.000) regional studies of each field are conducted and then by scale reduction we pass on to the thematic maps covering the whole territory.

The Atlas in made up of 40 maps with the format 46x48 cm. They are general geographic maps in two variants: only linear elements with hipsometric colours and shading. This serves also as preliminary work for the National Thematic Atlas.

For the first time, a complete index of geographical names and toponyms of the country (all in all 10.000) will be attached to the Atlas.

4. The Complex Geographic Atlas of Albania. Being the first attempt in the field of Albanian Cartography it was conceived in such a way as to benefit a map system, naturally organized and interconnected, so as to give:

- The features and interdependant relations of nature, population, economy, culture and management.

The results of our research work reflecting the development of the whole country.

The possibility to conduct complex studies on the content of the Atlas about the present and the future of the country.

- The possibility to define as accurately as possible the rational exploration of natural resources, the protection and revivial of the environment, the organization of man power, the development of economy and culture.

The Atlas will give maximal, condensed information on a national scale about the complex relationship: nature-society. It also aims at becoming a necessary tool for the specialists of each branch in his research work as well as in planning, management and direction.

In this context the Atlas will contain five chapters: Nature, Population, Culture, Administration - five broad subjects treated in thier whole scientific range. The number of maps contained will be 165 all in all.

The scale of the biggest map in the atlas will be 1:500.000. the other sacles vary up to 1:1.250.000. The page format will be 52x72.5 cm, having in mind the maximal desk format for the optimal information imparted by the map system.

It would be possible later to publish an English -Albanian Version with a format 32x42 cm and the basis map at the scale 1:800.000.

Each chapter of the Atlas will have an introductory page. We are against the explanatory texts, proceeding from the right assumption that a map gives as much knowledge about a definite subject as a written book does. What's the use of them? To complete scanty legends or to clarify the complicated and obscure ones? This would oblige us to make a division of 30% text and 70% maps.

If there is concise legend which tells all the story of the map, then there is no need for an accompanying text. If there is desire to get more information on the qualities and features of the phenomena, not available from the map, them the user has to turn to publications other than cartographic. This would help also in the case of maps of deeper content.

All these works which either have been realized or are in the process, have been sustained by the passionate cooperation between the specialist of the theme and the cartographer. One must point out the scarce technical possibilities which hamper and delay the realization of the tasks. An instance of this could be work which is carried out mainly by hand, not to mention here the numerous difficulties with the printing press.

If this modest presentation will serve to draw the attention of the Presidency of this International Society towards a technology transfer of the modern computerized cartography to my country, I assure you that the Albanian Cartography will rise from the present confusion and rank among advanced international levels.

Lastly, the publication of the Complex Atlas of Albania will be a remarkable event for our country nor only for its dimensions, but also for the fact that it will mark the gradual change of the Albanian mindset, making it conscious of the benefits of cartography in the effective management of economy, in the proper, rational use of natural resources, in the protection of environment. This achievement will finally mark the end of the isolation, thus showing the superiority of international cooperation and integration.

Samini. E, Seferi. E

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Glance and misery of school atlases

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I. INTRODUCTION

School atlases are often the first maps what a man meets with. No wonder that they can influence his attitude to maps for the whole life. School atlases of our time are altogether very complicated works and the level of their technical execution is considerably high. More over some atlases have been compiled very tastefully so that maps together with more and more used pictures, aerial photographs,satellite imageries and diagrams bring literally a feast to eyes.

However,all this need not be enough for good serving to the purposes that have been these atlases made for. Alas,often neither pupils nor teachers can build up a clear and rememberable picture of reality from those maps.

Remarkable part of the content of contemporary cartographic journals has been occupied by articles dealing with computer-assisted cartography. They show how to use computer technique for saving work of cartographers. It seems that cartographers think first to themselves but not to the map users which the maps are designated for.

But map users are not interested at all in the techniques that have been used for producing of maps. They only demand maps that they could read right and easily. Nevertheless geographic maps in school atlases contain thousands of exotic towns,and pupils only with difficulties search among them those which they are learning about.

Great overfilling and illegibility like that has been limited not only for school atlases. The most famous Swiss cartographer Eduard Imhof had once expressed in his review of some atlas such unfavourable critic that a hurted publisher of referred atlas visited him immediately. Professor Imhof gave him a magnifying glass,showed him different names of places in his atlas and asked him to read them. Reading ended wrong,the publisher became sad,nevertheless he stated: "Fortunately, the most part of it is already out of print."

However,geographical and political maps are in most cases better arranged than thematic maps. Dominating as regards incomprehensibility are economic maps. The economic maps could make perhaps happy some crossword- and puzzle lovers, but as aids for teaching geography are hardly to use.By my experience all what a child has kept in mind from a complicated economic map of China with sixty items legend is nothing but rice and Peking.

II. THREE MAIN DEFECTS OF SCHOOL ECONOMIC MAPS

Almost every atlas works with other map symbols and with different methods of cartographic representation,but one defect have all school atlases in common: overfilling. They are so much stuffed and overloaded by map symbols and lettering, as the medieval horror vacui (fear from emptiness) staid in cartographers: that forced them in Middle Ages to fill unknown countries and uninvestigated areas by pictures of fictitious creatures and monsters. The overfilling of school economic maps does not correspond to the amount of knowledge what a pupil is obliged to acquire. On the contrary: it prevents him to create his own simplified map picture in his mind. The maps like these are out of sense.

What is the cause of this overfilling? Evidently that the cartographer does not imagine himself inthe position of scholar. Cartographer puts forward instead of vivid supplement of textbook only reduced scientific maps: the parts of atlases devoted to the children's mother country used to be only a miniature of national atlas. In particular countries is too much minerals and agricultural products, though if they are of negligible importance. Also the amount of industrial cities is absurdly high. In spite of that individual city symbols are further divided in accordance with several partial industrial branches.

For example in the economic map of Japan some school atlases destined for 11-15 years old children contain:

1. As much as 15 kinds of minerals. I think that children should mainly know that there are generally no significant mineral deposits at all (the biggest is zinc with 2 % world-ratio).
2. As much as 17 kinds of agricultural products. Maybe four would be enough (fishes,citruses,tea,rice).
3. As much as 85 names of industrial cities. When I had tried it myself,I achieved to write by heart only 16 cities that means less then 20 %. I should be happy if children knew 3-5 cities.
4. As much as 21 kinds of industrial branches. Several pictures of concrete products (car,TV set,camera,ship) would be better.

Each of symbols for minerals,agricultural products and industrial branches is used several times in the same map,thus the total amount of symbols reaches up hundreds.

TABLE 1. Amount of kinds of features in economic maps of Japan in school geographic world atlases.

	minerals	agricultural products	industrial cities	industrial branches
Seydlitz Weltatlas. Berlin 1985.	6	4	85	21
Školni atlas světa. Praha 1989.	15	17	57	12
Atlas für die 6. bis 11.Klasse. Gotha 1985.	9	6	63	18
Geografičeskij atlas dlja devjatogo klassa. Moskva 1988.	10	7	48	15
Unsere Welt. Berlin 1990.	6	4	53	18
Österreichischer Oberstufenatlas. Wien 1981.	8	10	58	8
Harms Schulatlas. München 1990.	8	5	46	9
Földrájzi Atlasz a közepiskolák számára. Budapest 1989.	6	7	52	4

What is the second essential defect of school economic maps? The second defect is very wrong and quite insufficient distinction of significance of the represented features by means of height and colour of the map symbols. Owing to that a map reader is not able to appreciate at first sight what is the significance of the represented phenomena in particular country or in the whole world.

What is the reason of it? In the main this that map authors make themselves no pains with changing of map symbols size. So that the symbol of the world most important deposit has often the same height, as a symbol of an inferior one. In case that several sizes are used, intervals of value scale are divided uncorrectly so that most of symbols belongs into the only size category and has the same height.

The secret what criterion for appreciation of significance of represented phenomena was used, the map authors like to keep for themselves. Only rarely the criterion used for representation of mineral production is referred (for example world-ratio percentage). However, if there are more symbols of the same mineral inside one country, it is not clear whether the height of each symbol refer to the whole world (as stated in legend) or to the distribution of deposits inside the country only (legend is not valid?).

The third deffect of school economic maps is improper choice of map symbols. The used symbols are very small,badly legible and hard to remember. Their height in atlases used to be about 2 mm (1 line) - like a minuscule at typewriter. In addition symbols are sometimes situated inside small square frames so that the effective area of a symbol falls to 1 square milimeter only. Rather than legibility we can speak about illegibility. Colour of the map symbol on colour background is sometimes almost getting lost. In other cases the colours of different symbols are so similar that they are mistaken to one another. At some other time the symbols are so minute and few distinguishable that they must be studied through a magnifying glass.

The ability of keeping symbols in mind is another point. There is no homogeneity of atlases,in every atlas are used different symbols. Authors of atlases have a special liking for geometrical symbols that are the worst to remember.

Overfilling of maps and bad distinction of significance of the represented phenomena is on the whole easy to improve. On the contrary changing of map symbols is quite another matter. Existing symbols have been used for tens of years,they are characteristic for every atlas and only a mere idea to replace them by other symbols meets with aversion of map producers, because it threatens with increase of production costs.

III. PROPOSALS FOR IMPROVEMENT

The abovementioned three lacks of school economic maps meet geography teachers and their pupils every day with. However,these lacks make no troubles to cartographers of course. Why it should do at all if they were not forced to teach on the basis of these maps? Certainly it would be interesting to find out,how many facts and how correct would such adult map author keep in mind from a map that he compiled himself as a help of instruction for children of 11-15 ages.

There can be different views how this situation could be changed. However, each of them should respect the following facts:

1. Children have the right to get maps that make their learning easier and not on the contrary more difficult.
2. Cartographers have a duty to accord such maps for them.
3. The right of deciding whether maps perform their intent or not belongs to users: scholars and geography teachers.

School atlases are designated for scholars. That is why they must be simple. Alexander von Humboldt expressed it pretty nicely two hundred years ago, when he said: " Only empty maps remain into a mind!"

It is not worth to stuff plenty of data into a school map. More necessary is to choose, what in the represented area is really important, and this strong to point out. Thematic content in school thematic maps must directly crack to the reader's eyes instead of leaving him to search as a detective in ballast of superfluous data.

However, how to do it? Let me to put forward several rules for removal of overfilling, for improvement of significance representation, and for better choice of map symbols, respectivelly.

A. Removal of overfilling

1. No framing of symbols.
2. Reducing of amount of represented phenomena: omitting of less known ones, fusing of closely related (e.g. wheat+rye+barley+oats=cereals).
3. Marking of regional specialities (e.g. spice, sisal) by lettering.
4. Using one piece of symbol only for the same phenomenon in each country in maps of continents or the whole world. More pieces only in the countries having more than conventional (e.g. 10 %) world-ratio (share in the world production. Total value of symbols of the same phenomenon in one country must not exceed the share of country in the world production.
5. Reducing of industrial city names.
6. Strong generalisation of land use boundaries.
7. Keeping little used areas in white colour.

B. Improvement of significance representation

1. Representing of significance by height of symbol in accordance with the world-ratio e.g. more than 20 %, 10-20 %, 5-10 %, 1-5 %.
2. The best criterion of significance is financial value of production. If it is not at disposal, then weight of minerals and products or number of domestic animals are applicable.
3. The thickness of transport representing lines has to be in accordance with maximum world reached value (e.g. number of trains per hour).
4. Optical proportion of symbols for minerals, agriculture and industry must express their mutual economic significance in the country one another.

C. Choice of map symbols

1. As far as possible choice that sort of symbols that are legible without legend.
2. Using chemical symbols for minerals, geometric symbols for fuels and compounds. Demarcating of fuel basin limits.
3. Using pictorial symbols for agricultural products and domestic animals. Supplying these symbols by lettering if they are extended in large areas.

4. Using of conspicuous colours for the most important phenomena. Choice of easily recognisable colours for land use.
5. Representation of industrial areas by colour areals without differentiation of industrial branches.
6. Using pictorial symbols representing typical industrial products instead of cutted circles or columns.

IV. ADDITIONAL SUGGESTIONS

I suppose that it is necessary to improve the contact between school atlases and geographical textbooks. Both could be made by following process:

1. Creation of compilation manuscript of map containing several times more data than children need. These data must be properly hierarchized: differenciated in accordance of their significance.
2. Compiling of textbook of regional geography on the basis of abovementioned maps. Marking in maps the facts that pupils should know in active way and in passive way. Neglecting of those features which pupils need not know.
3. Compilation of new maps showing to pupils what a level of their knowledge is expected. Then they will not be forced to work through a labyrinth of data having no use for them.

No doubt that for school atlases a substantial reduction,thin cover and narrow contact with textbooks are advisable. Maybe that for children better than thematic maps in atlases would serve simple maps in textbooks,applying immediately to the theme taught in the school. After all,there are countries where - as I know - no school atlases exist.

Questionable is writing of geographic names. In spoken language and in press mostly exonyms (deep-rooted names) have been commonly used. But cartographers in some countries prefer quite the reverse: foreign names are used and exonyms are mentioned nor in brackets. I personally recommend using of exonyms because we meet them commonly in press and literature and because exonyms only pupils do know to read and to pronounce correctly. That is why I prefer Cairo, Jerusalem and Canton against Al Qahirah,Yerushalayim and Guangzhou. Definitely in no case we may suffer names in school atlases differing from names in textbooks.

V. CONCLUSION

Economic maps in school atlases have to serve for 11-15 years old children. By that time these maps are absurdly complicated and they are looking so that not only pupils but also teachers can decipher only with great difficulties, what cartographers had enciphered into them. It is impossible from maps like these to create the correct conception of significance represented phenomena even for me,a university cartographer.

It is necessary to say clearly: if a map has to be of value for scholars, they must read data better and more easily in map than in texts or in tables. And it is a matter of cartographers to get to scholars a map like that. Otherwise others will do it instead of cartographers. Then cartographers could meditate,how to earn theirs livings.

After all, let us remember words of Barbara Bartz-Petchenik in the Canadian journal Cartographica eight years ago:
"Who pays us to make our livings as cartographers,and why?"

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Map Based Information Systems IV

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Scale change via hierarchical coarsening: cartographic properties of quaternary triangular meshes

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Abstract

A data model and coordinate system for global spatial data is described: called *quaternary triangular mesh* (QTM), this model identifies geographic locations as a nested hierarchy of triangles created by subdividing the faces of an octahedron embedded in a planet. At each successive level of subdivision, each facet begets four children, each blossoming forth to occupy slightly more than one-fourth its parent's area. After 16 levels of subdivision, facets are roughly the size of Landsat pixels. By the 30th level, the planet is covered by millions of trillions of facets, each about one square centimeter in area. Once coordinates of punctiform, linear and polygonal digital cartographic features are encoded into hierarchical addresses, they may be retrieved at any level of detail (doublings of scale), as desired. QTM addresses can be retransformed into geographic coordinates by selecting centers of triangular facets or at other locations within them (no unique mapping from QTM to latitude and longitude exists). Transformation between QTM and spherical coordinates regularizes the spatial distribution of coordinates in filtering them through a triangular mesh, coarsening features as scale decreases. This paper explores this approach to scale-filtering and discusses its implications for map display and generalization. Its useful properties are described, as well as some of its potential cartographic drawbacks. Figures illustrate QTM's properties and its filtering effects on linear features captured at certain scales; each coordinate is deprojected to latitude and longitude, transformed to a QTM address at a precision appropriate to its scale or accuracy, then reprojected into plane coordinates for display at several reolutions. Statistics and equations quantify aspects of the QTM hierarchy, which is also discussed as a sampling framework that can help to identify fractal dimensionalities, self-similarities and scale-dependencies lurking within map features. The paper concludes with a discussion of cartographic problems that QTM encoding of map features can address, perhaps even solve.

A Multi-scale Global Spatial Data Model

In a series of papers going back nearly ten years (Dutton, 1984; Dutton, 1989; Dutton, 1990; Dutton, 1991; Dutton, 1992; Goodchild and Yang, 1992), a data model has been described that encodes geographic locations at a hierarchy of scales, resolutions and accuracies. Originally intended to represent terrain relief, the approach has more recently been directed at storing, retrieving and manipulating planimetric features, using a hierarchical coordinate system to encode terrestrial locations (specified as latitudes and longitudes) as quadtree addresses. The quadtree cells specify triangular facets of a sequence of polyhedra that represent the figure of the Earth with increasing precision. This model has been given the name *Quaternary Triangular Mesh*, as it is a regular tessellation of triangular facets into four similar (although not identical) facets. Computationally, it is a quadtree structure; unlike most quadtrees, however, it does not tessellate a plane into rectangular blocks. Rather, it recursively partitions a sphere into triangular facets in the same manner that a geodesic dome approximates a sphere, although with much higher breakdown frequencies (Popko, 1968). The form and organization of the QTM framework are illustrated in *Figure 1*, and its most salient properties are discussed below.

Scale Sensitivity. QTM has two related properties that make it useful for encoding map features:

1. Each coordinate can be encoded to a level of precision appropriate to its accuracy, lineage and importance.
2. Geographic coordinates for any point can be retrieved at a hierarchy of resolutions (doublings of scale) less than the finest resolution stored for it.

While the model neither precludes nor penalizes specifying a level of accuracy for each coordinate, typically each feature or feature class would be encoded to a uniform level of accuracy, then retrieved at lower levels of accuracy depending on the purpose at hand. This could take place underneath the existing storage mechanisms of the production system that manipulates coordinate data, guided by users' commands and scripts, from algorithms and potentially from knowledge-based inference systems. That is, the data structures and algorithms used by the production system need not be modified, as the data presented to them would be identical in form to what they currently manipulate. What would change is the representation of spatial data at a very low level (beneath coordinates), plus the addition of software to encode and decode between QTM and geographic coordinates (storing and retrieving scale/accuracy measures as well as locations), and other software that can use these measures to identify spatial relationships. Precision and accuracy of QTM encoding is summarized by *Table 1*, which itemizes the number and sizes of QTM quadrants across 32 levels of detail, relating them to data storage units, map resolution and map scale.

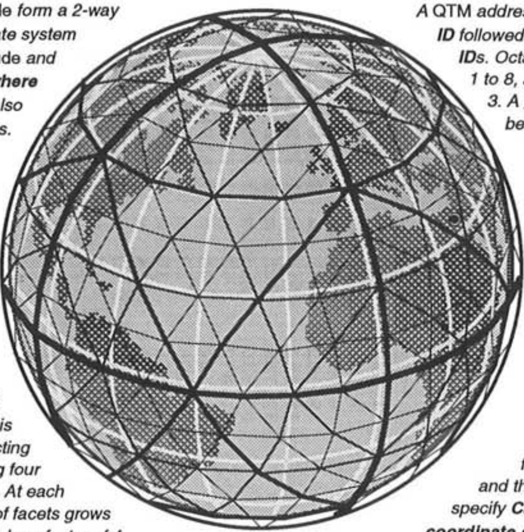
Table 1 presents the number and size of triangular quadrants in a Quaternary Triangular Mesh fitted to the Earth (approximated as a sphere with a circumference of 40,000 km). *QUADRANTS* counts the number of triangular facets per octant; *DIVISIONS* counts the number of quadrants along each octant edge. The size of each quadrant is given in terms of its edge length (*RESOLUTION*) and the spherical area it covers (*AREA*). While *RESOLUTION* and *AREA* are per quadrant (referring to average unit triangular facets) the counts of *QUADRANTS* and *DIVISIONS* are totals for each QTM Octant; multiply numbers in these columns by 8 to account for the entire planet. Resolution and area figures vary slightly across the planet; at each level, the largest quadrants (at octant centers) have approximately $\pi/2$ times the area of the smallest quadrants (at octant vertices), and these extremes lie about 6,700 km apart. *BITS* tallies the number of binary digits needed to store QTM addresses at each level of detail (including 4 bits for Octant ID).

Encoding and Decoding Coordinates. Figure 1 illustrates how the QTM address that locates greater Cairo relates to latitude and longitude. In the lower-right corner, an octahedron is mapped onto a square using the Zenithial Ortho-triangular (ZOT) projection (Dutton, 1991), centered on the North Pole (the South Pole occupies the four corners). Latitudes are measured along the horizontal and vertical axes; Longitudes are measured along opposing diagonals. Cairo's QTM address (10320130) is shown as a nested series of six triangles within Octant 1. As the diagram indicates, however unesthetic it may be strike one a map projection, ZOT's rectilinearity and uniformity simplify computation of QTM addresses. An algorithm has been developed to transform spherical coordinates to into QTM addresses by projecting them into the ZOT domain, where uniform triangular facets and their QTM addresses are recursively computed by linear interpolation using simple arithmetic and logic. The inverse algorithm, enabling production of geographic coordinates from QTM addresses, has also been demonstrated. Other methods to perform such encoding (but which generate different sequences of triangular addresses) have been invented (Fekete, 1990; Goodchild and Yang, 1992; Otoo and Zhu, 1993). The ZOT transformation appears to be as efficient as any of the methods used by other authors, and can be visualized more easily than most.

The QTM tessellation assigns to each node in the hierarchy (starting with the six octahedral vertices) a *basis number* from 1 to 3 in an alternating sequence. This generates the numbering patterns shown in *Figure 4,* in which all facets incident to a given node are assigned its basis number as their terminal digit. Central facets, which are always numbered zero, have no basis node. When projected to the ZOT plane,

Quaternary Triangular Mesh made simple

Latitude *and* Longitude *form a 2-way grid;* QTM*'s coordinate system has three axes.* Latitude *and* Longitude *describe* **where** *a thing is;* QTM *can also say* **how big** *a thing is.* Lat–lon *coordinates are tuples of* **real numbers;** QTM *codes locations as strings of 2-bit* **integer IDs.**

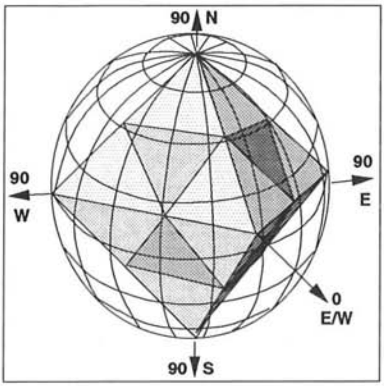


QTM *is a* **mesh** *covering a planet that starts out as an* **octahedron**. *Each of its 8 triangular facets is subdivided by connecting its midpoints, yielding four triangular* **quadrants.** *At each iteration the number of facets grows and their areas shrink by a factor of 4.*

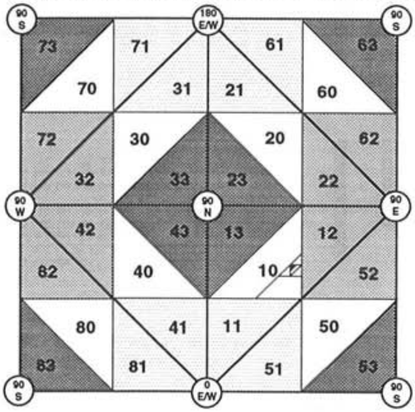
A QTM *address consists of an* **octant ID** *followed by a string of* **quadrant IDs**. *Octants are numbered from 1 to 8, and quadrants from 0 to 3. A geographic position can be recursively encoded as a* QTM *code containing many digits as may be appropriate to locate whatever is there, as accurately as is reasonable.*

The black dot shown in Africa locates the city of **Cairo,** *at 29.88ºN, 30.53ºE. The* QTM *address of* **Cairo** *is* 10320130, *where the first digit is an* **octant ID** *and the following seven digits specify* **Cairo***'s location in* QTM*'s* **coordinate system** *to within 40 km.*

An Octahedron Embedded in the Earth



Numbering of QTM Octants and Quadrants



The orientation of the octahedron fixes the location of each facet and its quadrants. Systematic assignment of IDs to quadrants gives each address a precise geographic identity. QTM's numbering scheme creates clusters of quadrants around mesh nodes that always have the same last digit, as illustrated by the first-level quadrants shown above.

Figure 1

Table 1

Quadrant Statistics and Map Scales for QTM Octants across 34 levels of detail

QTM LEVEL	BITS	QUADRANTS	AREA	DIVISIONS	RESOLUTION	SCALE FRACTION	STANDARD SCALES
1	4	4	16,120,936 kmsq	2	5,000 km	1.00E+10	
2	4	16	4,030,234 kmsq	4	2,500 km	5.00E+09	
3	4	64	1,007,559 kmsq	8	1,250 km	2.50E+09	
4	6	256	251,890 kmsq	16	625 km	1.25E+09	
5	8	1,024	62,972 kmsq	32	313 km	6.25E+08	
6	10	4,096	15,743 kmsq	64	156 km	3.13E+08	
7	12	16,384	3,936 kmsq	128	78 km	1.56E+08	
8	14	65,536	984 kmsq	256	39 km	7.81E+07	1:100,000,000
9	16	262,144	246 kmsq	512	20 km	3.91E+07	1:50,000,000
10	18	1,048,576	61 kmsq	1,024	10 km	1.95E+07	
11	20	4,194,304	15 kmsq	2,048	5 km	9.77E+06	1:10,000,000
12	22	16,777,216	4 kmsq	4,096	2 km	4.88E+06	
13	24	67,108,864	960,883 msq	8,192	1 km	2.44E+06	1:2,000,000
14	26	268,435,456	240,221 msq	16,384	610 m	1.22E+06	1:1,000,000
15	28	1,073,741,824	60,055 msq	32,768	305 m	6.10E+05	1:500,000
16	30	4,294,967,296	15,014 msq	65,536	153 m	3.05E+05	1:250,000
17	32	1.7179869E+10	3,753 msq	131,072	76 m	1.53E+05	1:100,000
18	34	6.8719477E+10	938 msq	262,144	38 m	7.63E+04	
19	36	2.7487791E+11	235 msq	524,288	19 m	3.81E+04	1:50,000
20	38	1.0995116E+12	59 msq	1,048,576	10 m	1.91E+04	1:25000
21	40	4.3980465E+12	15 msq	2,097,152	5 m	9.54E+03	1:10000
22	42	1.7592186E+13	4 msq	4,194,304	2 m	4.77E+03	1:5000
23	44	7.0368744E+13	1 msq	8,388,608	1 m	2.38E+03	1:2500
24	46	2.8147498E+14	2,291 cmsq	16,777,216	60 cm	1.19E+03	1:1000
25	48	1.1258999E+15	573 cmsq	33,554,432	30 cm	5.96E+02	1:500
26	50	4.5035996E+15	143 cmsq	67,108,864	15 cm	2.98E+02	
27	52	1.8014399E+16	36 cmsq	134,217,728	7 cm	1.49E+02	1:100
28	54	7.2057594E+16	9 cmsq	268,435,456	4 cm	7.45E+01	
29	56	2.8823038E+17	2 cmsq	536,870,912	2 cm	3.73E+01	
30	58	1.1529215E+18	1 cmsq	1,073,741,824	1 cm	1.86E+01	
31	60	4.6116860E+18	14 mmsq	2,147,483,648	5 mm	9.31E+00	1:10
32	62	1.8446744E+19	3 mmsq	4,294,967,296	2 mm	4.66E+00	
33	64	7.3786976E+19	1 mmsq	8,589,934,592	1 mm	2.33E+00	
34	66	2.9514791E+20	0.2 mmsq	17,179,869,184	0.6 mm	1.16E+00	1:1

each set of four siblings are arrayed as four identical, right isoceles quadrants formed by bisecting the edges of their right isoceles parent triangle. The nodes that appear at the child level are at the midpoints of the parent's edges, as *Figure 1* illustrates. These nodes are assigned basis numbers according to the formula $C = 6 - (A + B)$, where A and B are the basis numbers of the two nodes defining the parent's edge being bisected (A and B will always have different IDs, and C will be different from either). Child quadrant IDs are assigned by determining which child quadrant a point being encoded falls into, and numbering it with the basis number of the closest parent vertex (that is, of the closest corner – not midpoint – node). Should a point fall into a central quadrant, it will not be losest to any node and will be numbered zero. The digit assigned (1, 2, 3 or 0) will be appended to the parent's QTM address, refining its precision. Using the ZOT transformation to identify which quadrant a point falls into simplifies computation, as only one, two or three comparisons of displacements along the parent's X and/or Y axes need be made (tests of inequality with respect to edge midpoints). By renormalizing the dimensions of quadrants at each level, this process can be carried out recursively without danger of exceeding the limits of machine precision.

Qualifying Coordinates. Source map scale, digitizing error parameters and inherent uncertainties can be recorded in spatial databases as metadata, and consulted in the course of generalizing map features. Currently, there is no set approach to doing this, although increasingly there are institutional requirements for storing metadata.[1] *Figure 2* (adapted from Dutton, 1992) illustrates opposing approaches to building positional metadata into a spatial database to enable retrieval of scale-specific coordinate data. Encoding coordinate tuples into QTM is simpler to implement than is carrying positional metadata at the feature, feature class and overlay levels, the approach most often taken by geographic information systems (GIS) that are equipped to handle data qualifiers (usually via user-written protocols and user-specified relations). Were QTM to be used as a coordinate notation, new types of information would become available, and new procedures for analyzing and utilizing them would be needed, as current GIS architecture does not regard space hierarchically. Some of these operations do exist in raster- and quadtree-based systems, but these employ rectangular decompositions of planar space. The only prototype systems of which we are aware that triangularly decompose planets are those of Goodchild and Yang (1989) and Fekete (1990).

Space Occupancy. Being a type of area quadtree (Samet, 1990), QTM completely partitions space. In this respect it is also a raster data structure, however there are important differences that distinguish QTM, rasters and rectangular quadtrees:

- ***Rasters and rectangular quadtrees are based on planar tessellations; because of this:***
  - ***Large geographic regions are difficult to represent without locational, scale and shape distortion***
  - ***Geographic locations of pixels may be ill-defined***
  - ***Consistent, accurate registration of such data is difficult***

QTM's tessellation does not exhibit these problems. We orient it to a sphere in a well-defined way — although other orientations could also be used (Dutton, 1991). Its facets completely cover the planet at all levels of detail. Each of them has a unique integer identifier, systematically defined. Every QTM address thus has specific locational meaning which never varies, identifying a spherical triangle having well-defined vertices, edges and area. Sibling triangles properly nest within their parent triangles, although they do vary in shape (systematically with latitude and longitude) and area (sibling area sums are diminishingly greater than parent area). Being functions of location, these variations are inherently recoverable.

An Actual Fractal. As it is recursively defined and completely self-similar, the QTM grid of triangles is a deterministic fractal (Mandelbrot, 1982). These properties of the grid can be exploited to analyze digitized map features — particularly coastlines and rivers — to estimate their fractal dimension and degree of self-similarity. Experiments carried out by the authors using the World Data Bank 1 (WDB1) digitization of

[1] The new U.S. Federal Spatial Data Transfer Standard (SDTS), FIPS 173, is an example of forces that are causing more serious attention to be paid to metadata. There are fewer forces specifically impelling mapping organizations to utilize metadata in production activities, but economic and quality concerns are leading them to do this.

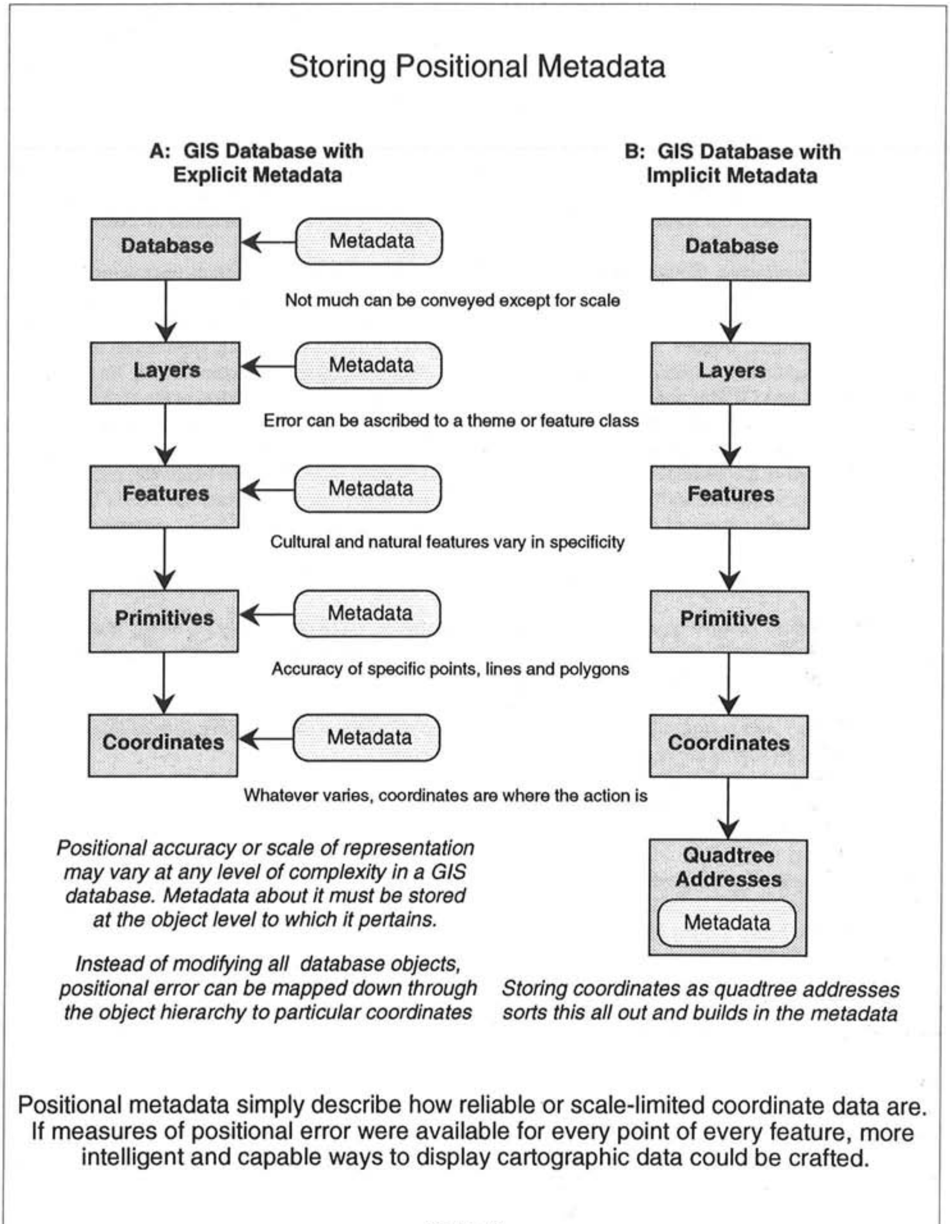

Storing Positional Metadata
A: GIS Database with Explicit Metadata
B: GIS Database with Implicit Metadata
Database
Metadata
Not much can be conveyed except for scale
Layers
Metadata
Error can be ascribed to a theme or feature class
Features
Metadata
Cultural and natural features vary in specificity
Primitives
Metadata
Accuracy of specific points, lines and polygons
Coordinates
Metadata
Whatever varies, coordinates are where the action is
Database
Layers
Features
Primitives
Coordinates
Quadtree Addresses
Metadata
Positional accuracy or scale of representation may vary at any level of complexity in a GIS database. Metadata about it must be stored at the object level to which it pertains.
Instead of modifying all database objects, positional error can be mapped down through the object hierarchy to particular coordinates
Storing coordinates as quadtree addresses sorts this all out and builds in the metadata
Positional metadata simply describe how reliable or scale-limited coordinate data are. If measures of positional error were available for every point of every feature, more intelligent and capable ways to display cartographic data could be crafted.

Figure 2

coastlines and national boundaries, encoded coordinates as QTM addresses down to roughly 100 meter resolution (16 QTM levels). Versions of these lines were then retrieved at doublings of resolution, from 100 meters to 100,000 meters, converted back to geographic coordinates and segment lengths compared to resolution (simulating "divider" measurements). This analysis yields "Richardson diagrams" (Richardson, 1961), such as the one in *Figure 3*, which are one way to estimate fractal dimensionality. Initial results indicate that this technique reveals some interesting cartographic properties of boundaries:

- ***Fractal dimension may be constant within certain ranges of scale***
- ***Self-similarity may be observed at intermediate resolutions***
- ***Useless resolutions finer than digitizing scale may be identified***

These results are commensurate with research using other digital cartographic datasets (Buttenfield, 1989; Buttenfield, 1991). While *Figure 3* represents an aggregation of boundaries having a variety of properties, dimensionalities and degrees of self-similarity, the analysis could be performed for individual feature elements (arcs and polygons) to identify lower and upper scale limits, outside of which cartographic generalization techniques may give unreliable results, and probably should not be attempted.

Contextual Generalization. Among the more vexing challenges of automating map generalization is how to employ contextual evidence in representing features that compete for space. Such dilemmas take many forms: When place names become crowded, which should be displaced, which removed? At what scale should a group of islands be coalesced or eliminated altogether? Which contours should be displayed? Where should labels be placed? Where will road and river symbols overlap, and what should be done to resolve the conflict? These issues are closely connected to how spatial entities are represented by data models and how data models are built into data structures. Data models can constrain how data layers and feature classes are defined, how individual features are assembled, and what kinds of topological and attribute relations are maintained. The same properties that enable QTM to generalize the shapes of individual features may also enable it to negotiate conflicts between neighboring features that compete for space. To do this, a higher-level model of locations — inherent in QTM's coordinate framework — must be invoked.

Associating Locations. The QTM addresses of neighboring geographic points tend to (but need not) share leading digits. This means that they fall into the same initial triangular quadrants, and so long as they do are considered to occupy the same location. As an example, the Greek cities of Athens (located at QTM address 10300310...) and Sparta (at 10302310...) share the four initial digits 1030, which indicates that they lie nearby, within 200 km of one another. QTM records such facts without regard to what features points may participate in or how these are structured in a database, simply by modeling the proximity of locations. However, nearby points which fall into neighboring QTM quadrants may not have similar addresses, depending on where they lie with respect to the QTM grid. This problem — relating proximal locations lying in adjacent hierarchies — occurs in all area quadtrees, and underlies many objections to utilizing such representations to handle geographic data. To our knowledge, QTM is the only quadtree scheme that formally addresses this problem by defining nodal regions.

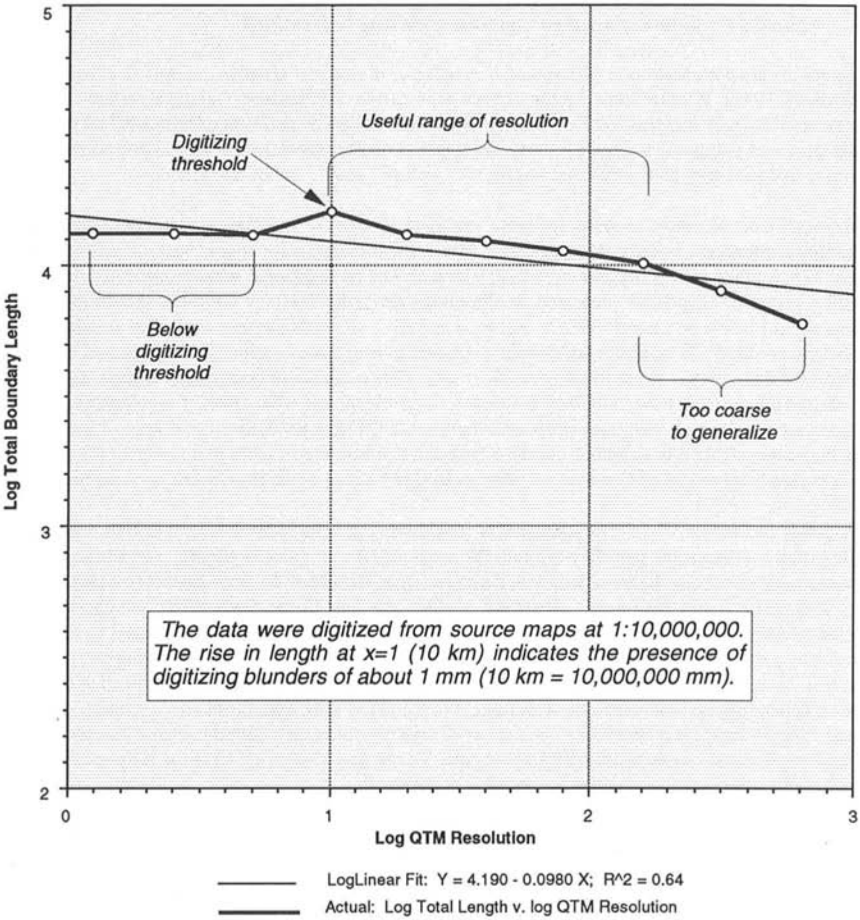
QTM incorporates two senses of location, one that relates to areas (quadrants), another that relates to points (nodes in hierarchy of quadrants). As quadrants are space-filling at all levels, their codes are used to encode coordinates for storage and retrieval. In order to associate points that lie close together, but not in the same quadrant, it is very useful to identify the node in the mesh nearest them. This is because all points proximal to a given node at some level of detail can be considered to occupy that node's location. In QTM space, *proximal location* is defined as occupancy of any of six quadrants centered at a node (which serves as a common vertex for those triangular facets). The node identified with a quadrant in one subtree also anchors quadrants in five other adjacent subtrees — even those occupying different initial octants — describing a hexagonal region of nodal influence.[2] We call these nodal regions *attractors*, as all data with-

[2] Every node in a QTM hierarchy has six surrounding facets, except those at the vertices of the initial octahedron. These six singular points have four surrounding facets at every level of detail. Two of these vertices are located at the poles and four are on the equator, as *Figure 1* illustrates.

South America: Coastlines and National Boundaries

Chains from World Data Bank I with 50 to 200 points, encoded to 13 QTM digits, then retrieved at decreasing resolution, decoded , projected and measured.

Total Boundary Length as function of QTM Resolution (logs of km)



This is a "Richardson Diagram" of South America from World Data Bank 1. The regression indicates a fractal dimension of 1.098. There appear to be three regimes of self-similarity. The most interesting one is in the middle.

The four data points between x=1.3 and x=2.2 (20 to 160 km resolution) indicate a self-similar regime that has a fractal dimension of 1.1.

Figure 3

in them gravitate to a common central mass that defines their locus.

Dealing with Spatial Competition. The preceding discussion implies that attractors can be used to identify locations in QTM space that compete for space. This indeed is the case. These hexagonal regions knit together quadrants that are cousins, rather than siblings. Furthermore, attractors themselves have (and usually are) children, which are interior hexagons concentric to their parent and half its diameter. While it has its own properties, the numbering of attractors reflects that of quadrants, as *Figure 4* displays. When the QTM address of a point is retrieved from storage, the address of its attractor can be computed by an analytic function for use in spatial analysis. Data structures can be devised to identify attractors that a set of features have in common; these are locations that compete for space, where generalization will have to be performed, either under program or manual control. Each one explicitly relates specific coordinates from two or more features, allowing conflicts to be isolated and addressed with precision and economy.

Visualizing QTM Data

Every point representing an element of a feature will have a QTM address that encodes its geographic location and its scale, accuracy or resolution. Expressed as 64-bit integers (or pairs of 32-bit integers), this encoding expresses an octant ID (4 bits), followed by up to 30 quadrant IDs (60 bits). As *Table 1* shows, 30 digits locates a specific triangular planetary patch about the size of a shirt button. As few cartographic databases achieve this degree of precision, QTM encodings of their coordinates will tend to be have fewer than 30 digits, and for many map series fewer than 20. *Table 1* describes the precision associated with coordinates digitized from maps at different scales in terms of the depth of QTM encoding required to represent all detail that a map can convey; it assumes that well-behaved source maps are digitized to a resolution of 0.5 mm, which represents the smallest vector that a human can be expected to discern and trace (Tobler, 1988). Typical line weights also constrain map details to be above this size. To represent displacements of 0.5 mm at a scale of 1:1, a QTM address requires 34 digits. Given the fact that each successive digit in a QTM address doubles resolution and halves the scale denominator, working upwards through the hierarchy from level 34 to level 1 will identify the map scales that correspond to particular QTM resolutions, as the last two columns in *Table 1* present. Parameterized,

$$\textit{map scale} = 2^L / 2E{+}10, \tag{1}$$

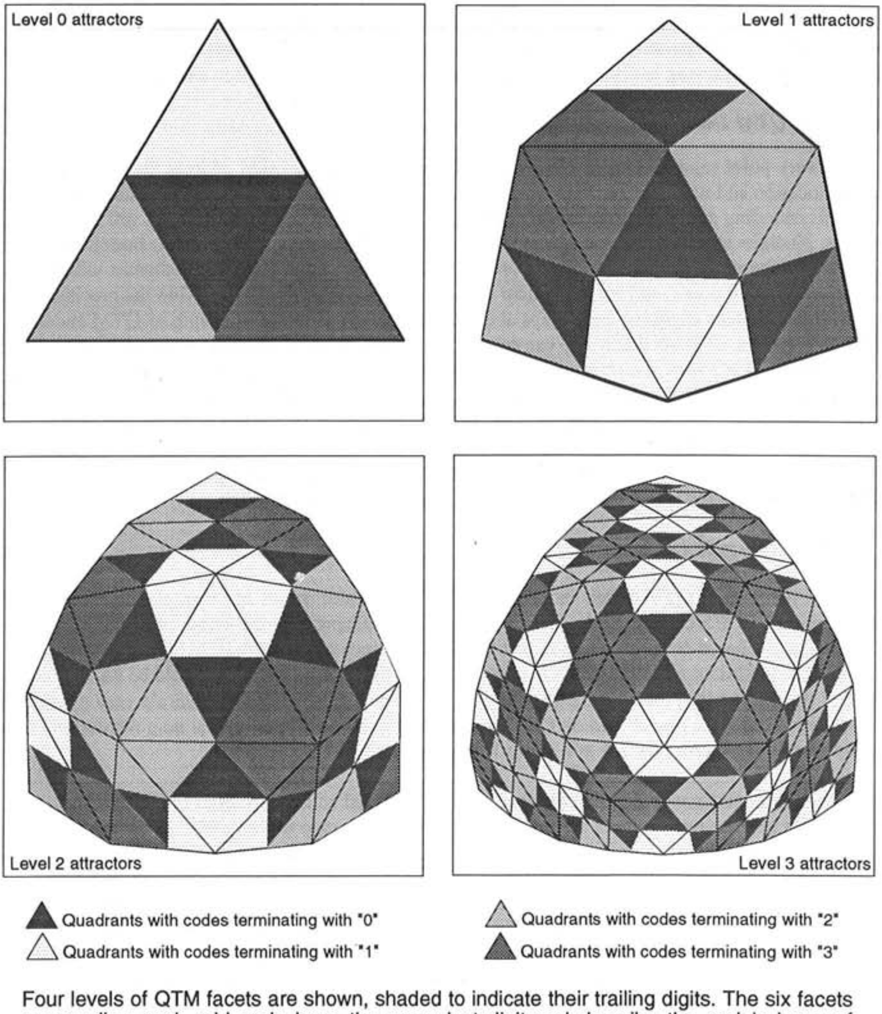
where L is the level of QTM detail, and 2^L is the number of times octant edges are divided at level L (the column labeled *DIVISIONS* in *Table 1*). The constant $2E{+}10$ represents the length of octant edges in half-millimeter units, based on an assumption that the circumference of the earth is 40,000 km. A similar table for spherical quadrilaterals is presented in a research note by Tobler (1989). It should be remembered that although the two tables present roughly equivalent measures, spherical quadrilaterals vary considerably more in area across the planet than do QTM's triangular facets (which at typical map resolutions vary in area by an average factor of $1/2 + \pi/4$, about 1.2854 or ±28.5%).[3]

Retrieving Synthetic Coordinates. At any level of detail, a QTM address specifies the location of a particular triangular facet, a well-defined area within which all points map to that address. To translate this address to geographic coordinates (before projecting into the plane), one must choose a mathematical point within the facet to represent the address. This location has no definite position; probabilistically considered, any point in the facet is as good as any other.The most logical and geometrically consistent location is probably the centroid of the facet, which is easy to compute. This has consequences affecting the quality of cartographic representations derived from QTM addresses. Specifically, retrieved points will always occupy vertices of a regular triangular grid; line segments will tend to be nearly equal in length and angles between them tend to be multiples of 60° (with 120° most typical). The human eye readily perceives the regularities imposed by such grids, and linear features filtered by such quantizations often look artificial.

[3] Goodchild and Yang (1992) note that at any given level of detail, the largest QTM quadrant (the one at the octant's centroid) has an area that is $\pi/2$ times that of the smallest quadrants (those at the octant's three vertices).

Development of QTM Attractors

Orthographic Perspective centered over one octant



Four levels of QTM facets are shown, shaded to indicate their trailing digits. The six facets surrounding each grid node have the same last digit and describe the node's locus of attraction. Attractors serve to relate quadrants between subtrees ("cousins") and as descriptors of spatial competition for features in their neighborhoods.

Figure 4

There is a more informed way to position coordinates retrieved to represent QTM quadrants than to mechanically select their centroids. It is also preferable to selecting random points within quadrants to represent locations, which can generate geometric and topologic inconsistencies. One may choose the centroid of a quadrant inferior to the one being retrieved for display (a lower-order digit in the QTM address being reprojected). Its ID is specified by one or more QTM digits immediately following the level of detail being retrieved (assuming that retrieval is not at the data's limit of QTM resolution). This strategy will also prevent features from appearing to wander from their original positions in the course of compiling maps across a range of scale, although this constraint may be selectively relaxed if desired.

How QTM Generalizes. If point locations need not be coarsened as scale diminishes, how exactly does QTM limit detail and generalize features? The answer is that, even if retained points do not significantly shift location, neighboring ones will tend to occupy the same quadrant as scale diminishes. As every QTM quadrant is a single location at its own level, it can logically represent only one coordinate. Coarsening resolution causes all point locations within the same quadrant to amalgamate as one, increasing their average spacing, thus thinning their graphic representation. Requiring that each quadrant be occupied by zero or one point simply expresses how QTM quantizes space.[4] The QTM model itself doesn't determine which of several coordinates occupying a quadrant should be eliminated, but these decisions will affect the quality of map generalizations. Rules are needed which generate appropriate and consistent geometric productions. A simple, rather arbitrary thinning rule is illustrated in *Figure 5*; (a) shows QTM-generalized vectors representing a cartographic detail, and (b) presents a smoothed version of (a). Smoothing is a reasonable transformation to use on line data when the entity a line represents can be assumed to be smooth.[5] The generalization rule can be expressed as:

- ***A quadrant remains empty when its four children are all empty;***
- ***When one child contains data, its centroid is used to position the point;***
- ***When two children contain data, the second one's centroid is selected;***
- ***When three children contain data, the middle one's centroid is selected;***
- ***When four children contain data, the parent's centroid is selected.***

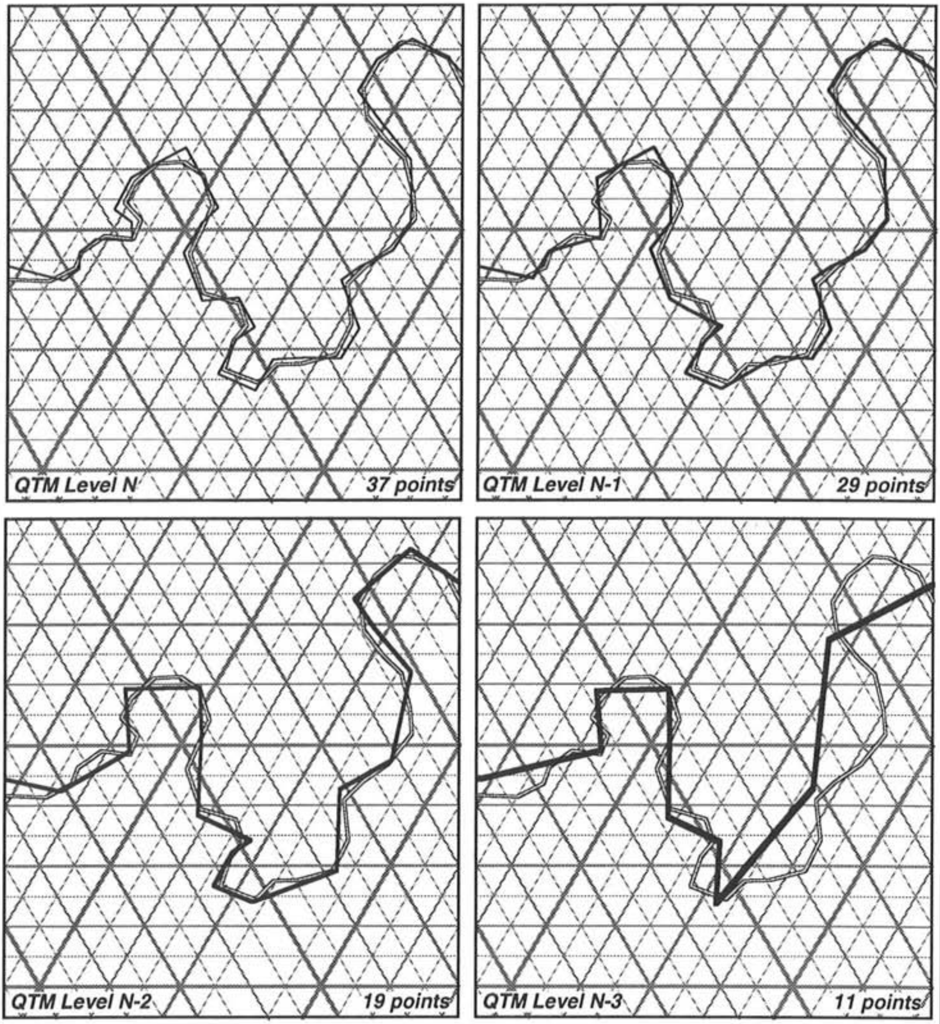
The centroid of a child can be its geometric centroid, or the one selected by this rule at a higher level of detail (that is, the rule can be applied recursively). The most arbitrary aspect of this approach is the case of two children; one will be selected, and the choice depends on which child's address is encountered first. That means different caricatures can result from traversing linear features in their "from-to" direction than when doing so in a "to-from" direction. An alternative approach to that case that avoids this bias is to select the centroid of the parent, even if it is not itself occupied (has no "0-child"). It is very likely, however, that one of two children will have a zero (central) address.

Alternative Realizations. As the above discussion indicates, *Figure 5* represents but one of dozens of QTM realizations that are possible by varying production rules and parameters. This particular one maximizes the stability of representation by assuring that retained points do not shift position. This may not always be desirable, as it may not necessarily lead to the most convincing generalization, although it may well do so. It is easy to relax the rule that defines how far the position of points in generalized realizations of QTM-encoded features can wander from their initial ("true") locations. A plausible way to guide this relaxation is:

[4] This statement needs to be qualified. It is possible for different features (or different parts of the same feature) to occupy a quadrant, depending one the operant generalization rules. The rule described here applies only to consecutive coordinates along a single polyline. If the polyline enters, leaves, reenters and leaves a quadrant again, the rule is applied to each group of coordinates associated with a particular transit.

[5] Smoothing is a large topic, and cannot be dealt with in detail here. It is possible, however, to encode QTM addresses to allow each point along a polyline to specify whether smoothing should be applied to it. This can be done by using the least significant digit in the address as a "smoothness flag" (rather than interpreting it as a quadrant ID).

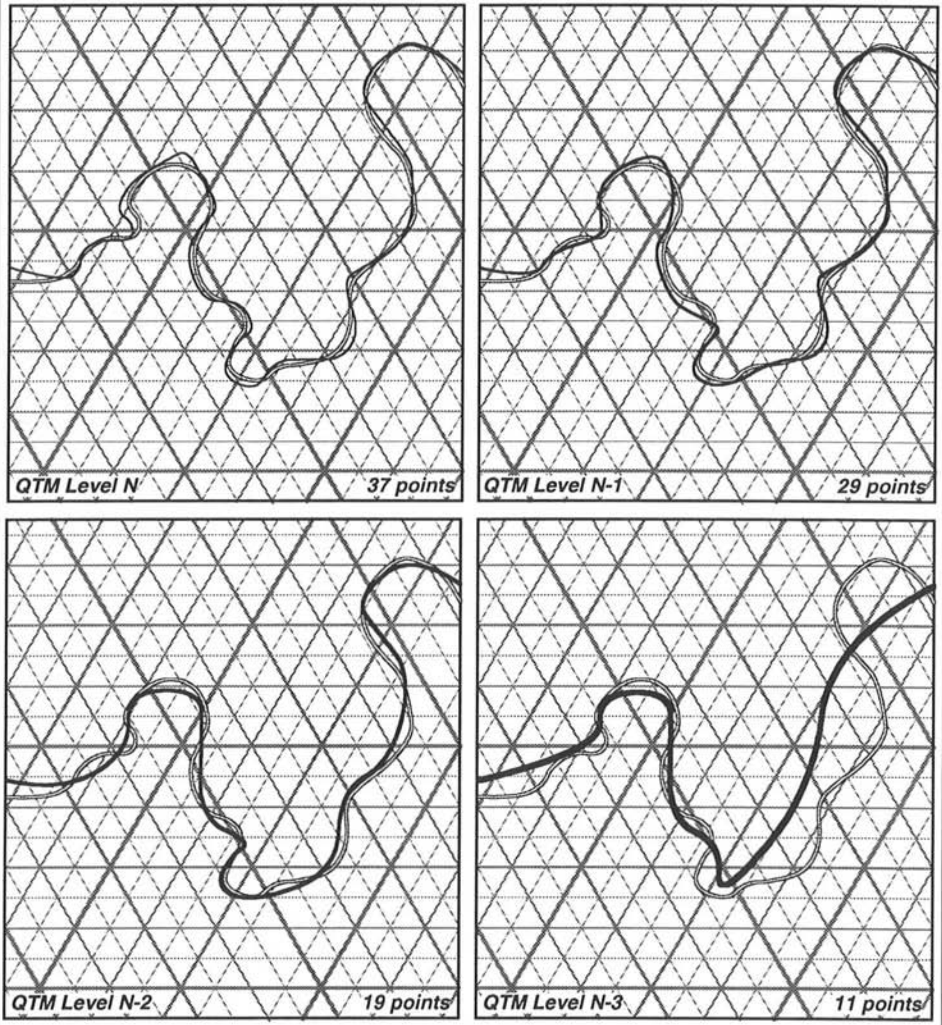
Line Generalization via Coarsening QTM Resolution



The cased line represents a digitized feature captured at approximately the resolution of QTM Level N. The solid lines are filtered versions of the feature sampled at original level N and the three levels below it in the hierarchy. Note that even though linear resolution halves at each level, the number of retained points does not, although it would if the feature were a simple curve. This indicates that the fractal dimension of the feature is greater than 1.0. See accompanying text for a description of the generalization rule used.

Figure 5A (unsmoothed)

Line Generalization via Coarsening QTM Resolution



The cased line represents a digitized feature captured at approximately the resolution of QTM Level N. The solid lines are filtered versions of the feature sampled at original level N and the three levels below it in the hierarchy. Note that even though linear resolution halves at each level, the number of retained points does not, although it would if the feature were a simple curve. This indicates that the fractal dimension of the feature is greater than 1.0. See accompanying text for a description of the generalization rule used.

Figure 5B (smoothed)

- ***Identify a finer scale at which to evaluate (sub-sample) point locations;***
- ***Decide whether resolution should be absolute or relative to retrieval scale;***
- ***Compute the number of QTM digits which corresponds to this scale;***
- ***Descend to that depth (resolution) to produce coordinates from QTM addresses.***

This "metarule"[6] determines how regularized a given realization will be, compared to how unperturbed it can be. It can be expressed as a parameter between 0 and 1, which quantifies the degree of regularization desired. The parameter, QS (*quotient of simplification*), is defined as:

$$QS = \frac{L_{max} - L_{res}}{L_{max} - L} \tag{2}$$

where L_{max} is the number of QTM levels at which a feature is encoded, L_{res} is the resolution at which it should be represented (L_{res} may be less than L_{max}), and L is the QTM level at which points are being retrieved (L is less than L_{res}). To give an example, suppose a map series has been digitized at a scale of 1:25,000, and coordinates of its features encoded into QTM addresses; these will have 19 significant quaternary digits ($L_{max} = 19$). If all 19 digits are always used to compute locations, then $L_{res} = 19$, and $QS = (19 - 19) / (19 - L) = 0$, whatever level of detail may be retrieved (no simplification is performed). Should retrieval be desired at 1:1,000,000, this establishes L as 13. To represent features at 1:1,000,000, coordinate data can be resolved to the following scales by specifying different values for QS:

Table 2

Simplification Quotients (QS) for Resolving 19-level QTM Features at Level 13

SAMPLING LEVEL	*EQUIVALENT MAP SCALE*	*QUOTIENT OF SIMPLIFICATION*
19	1:25,000	0.0
18	1:50,000	0.167
17	1:75,000	0.333
16	1:100,000	0.5
15	1:250,000	0.667
14	1:500,000	0.833
13	1:1,000,000	1.0

For example, $QS = 0.5$ specifies that the positional accuracy of coordinates retrieved for a map at 1:1,000,000 ($L=13$) will be that of a 1:100,000 representation of the data ($L_{res}=16$). What that representation turns out to be depends on what other rules and metarules are applied.

The parameter QS is very similar in concept to the Brownian Coefficient (H), which determines the fractal dimension of Brownian surfaces and lines, an important class of stochastic fractals (Roy et. al., 1987). The relationship between H and fractal dimension (D) is:

$$D = 3 - H \quad \text{for surfaces, and} \tag{3}$$
$$D = 2 - H \quad \text{for contours (Mandelbrot, 1982, p. 260).} \tag{4}$$

Because locations become more spatially autocorrelated as H increases, lower values of D have smoother realizations than higher ones. Realizations of QTM-encoded features are similarly affected by setting QS. The smoothness of features retrieved at a specific QS varies directly with the value used. Unlike H, however, QS is a relative measure, the value of which depends on two parameters: (1) the QTM level at which features are retrieved (L), and (2) the maximum number of levels stored for the feature (or presumed to be significant), L_{max}. If QS does behave like H, retrieval of addresses at different settings of QS might also affect the dimensionality of resultant polylines; the authors have not yet investigated this possibility.

[6] A metarule is a rule used to apply other rules, just as metadata is data that describes other data.

Conclusions

The capability to generate maps at a wide range of scales from a consistent digital database is the holy grail of automated cartography. While many computational techniques for feature selection and simplification, as well as symbol selection, scaling and placement have been developed, trustworthy automation of map generalization remains an elusive goal. Traditions, technical limitations and expediency have led map producers to maintain multiple versions of cartographic features for producing map series at various scales and for specific purposes. As mapping organizations complete a transition to digital-based production, the lack of systematic solutions to generalizing map features increasingly constrains the conduct and economics of their day-to-day operations.

Although vector representations are in theory scaleless, data they encode are always characterized by finite resolution and positional error, hence are scale-limited in actual practice. The errors derive from various sources: scale and accuracy limitations of source maps, infidelities in digitizing, subsequent geometric transformations, and inherent uncertainty about the shapes and locations of features. Whatever the origin, there is no way to recover the error terms from coordinates themselves. When they are supplied, positional error and scale parameters are stored elsewhere in a database, keyed to layers, feature classes and features, but rarely to individual coordinate tuples. Yet to render features at any scale, error and uncertainty must ultimately be dealt with at each coordinate location. Traditional, coordinate-based vector models do not have this inherent capability.

QTM may provide a way to handle "catastrophic" scale change (where cartographic self-similarity breaks down), as it can identify scales at which individual features must change form in order to alleviate crowding while remaining recognizable as resolution coarsens. Most cartographic generalization software does not handle such situations well. Muller (1991, p.259) advocates a

> ...catastrophic approach to generalization, recognizing the fact that the representation of phenomena at different scales may involve sudden large variations in the ways nature is being abstracted. This is evidenced by the abrupt changes that occur when a cartographic object is being geometrically simplified until it becomes conceptually abstracted (the polygon envelope of a church is replaced by a cross sign, for instance). Those 'catastrophes' may be pictorial (a double line highway becomes a single line highway), structural (an island becomes a peninsula) or categorical (the semantics for *coniferous* and *deciduous* trees are replaced by the semantic *forest*).

It may be more useful to handle catastrophes via expert rules than attempting to deal with them using algorithms. The QTM model provides a highly appropriate basis for applying many of the phenomenological transformation rules that cartographers may articulate.

In addition to its capability of documenting positional data quality, QTM and models like it address some longstanding challenges in cartographic generalization related to scale change. The paper has described how these problems can be made more tractable by modifying cartographic databases to encode locations at multiple resolutions in a single digital representation of map features. The data model it advocates is also capable of identifying locations where features may compete for space, as well as features that may be eliminated or coalesced at a specified scale. As we have described its application, QTM is fully compatible with vector topological data structures used in automated mapping and GIS, as long as geometric data is provided in geographic (spherical), rather than planar coordinates. A QTM infrastructure can support multi-scale map production from a single set of topological vectors. By coding cartographic features as sets of locations at appropriate precision, to be retrieved at various scales of representation, better computational methods for defining cartographic features, modeling their spatial relations, generalizing their complexity and symbolizing them on maps will arise.

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The conceptual design and realization for an object-oriented map database management system

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In this paper,the *object-oriented application and requirements of an* object-oriented database management system is introduced.The object-oriented database concept jointed with map database is expressed. Also this paper designs an data model for an object-oriented map database management system.

1.INTRODUCTION

In this paper,emphasis is placed upon the so-called object-oriented data models.Object-oriented approaches originatal in programming languages such as Simula and Smalltalk.The application of object-oriented ideas to database was spurred on by the apparent limitations of traditional relational technology when applied to some of the newer application. Typical examples are the *applications of database in computer-aided design*(CAD) , *map database* management system and geographical information systems.A common difficulty in all of these application areas is the gulf between the richness of the knowledge structures in the application domains and the relative simplicity of the data model in which those structures can be expressed and manipulated. Object-oriented models have the facilites to express more readily the knowledge structure of the original application.

2.THE OBJECT-ORIENTED APPLICATION AND REQUIREMENTS

"Object-oriented" is a descriptive lable which has been applied to a range of activities,including:

Object-oriented data modelling.This is the abstruction of the real world to a form appropriate for use by a digital system,which allows the properties of an object and its operators to be associated together (encapsulated) , and for specifical passing of properties between objects (inheritance).This allows a closer similarity in the model to the complexity of the real wirld than previous techniques for data modelling, such as entity-relationship modelling, *are able to do.They are not able to include* the required detail as easily as object-oriented data models can.

Object-oriented programming languages. Languages such as Smalltalk,C++, *Actor,are high level languages which allow* the programmer, among other things, efficiently to represent object which not only contain their own internal data model,but also contain their own operational functionality.

Object-oriented database management systems(OODBMS) . These are being developed in response to the need to handle highly complex data efficiently. Previous relational, or *hierarchical,databases were failing to do this.* OODBMS are more suitable than previous DBMS in such fields as multi-media database, map database or geographical information systems. Attempts at implementing successful object-oriented data modelling techniques also motivated the development of appropriate database management systems.

Object-oriented techniques seem to provide more appropriate *solutious* than previous attempts,in the requirement for handling, and using large amounts of spatially referenced data which require complex data models. We consider next just what are the distinguishing features of an object -oriented database.Mandatory features of an OODBMS should include the following:

Support for complex objects----built from simple objects by set, list and tuple;
object identity----the objects existence is independent of its values;
encapsulation-------both data and operations are in the object;
types or classes---either concept to be available;
hierarchies---------to allow inheritance between objects;
Presence of overriding----------redefinition of operators *according to type;*
overlading----------multiple application to types of operator name;
late binding-------run-time translation of operators, computational;
completeness-------any computable function can be expressed;
Provision of extensibility-----both system and user defined *types;*
persistence-------survival of data over process execution;
concurrency-------harmonious coexistence of processes;
recovery----------return after hardware or software failure to secondary storage;
management--------for invisible handling of very large databases;

Optional features of an OODBMS can include the following:
support for multiple inheritance---from more than one object;
type checking-----------at compile time;
distributed systems-----over multiple nodes;
design transactions-----for customised use;
versioning--------------managing alternative versions of data;

3.OBJECT-ORIENTED DATABASE FUNDAMENTAL CONCEPT

It is an important for reader to know very well these concepts such as generalization,specialization,aggregation and grouping.

Generalization

Generalization is the construct which enables groups of entities of similar types to be considered as a single higer-order type. For example, entities of type VILLAGE,TOWN and CITY may be merged and considered as entities of the single type SETTLEMENT. SETTLEMENT is said to be a generalization of VILLAGE,TOWN and CITY.

Specialization

Specialization is the construct which enables the modeller to define possible roles for members of a given type. For example, entities of type DRAINAGE might be considered occurrences of type RIVER,LAKE,WATER WELL and s on,depending upon the context in which we see them.

Aggregation

Aggregation is the construct which enables types to be amalgamated into a higher-order type,the attributes of whose objects are a combination of the attributes of the objects of the constituent types.Formally,the objects which are occurrences of the aggregate type are tuples, the components types. An example is the type POINT,which is the aggregation of type POINT-ID with two *integer types named X-COORD and Y-COORD, thus representing a point as having* two spatial coordinates.

Grouping

Grouping is the construct which enables a set of objects of the same type to form an object of higher level type.It is often stipulated that the sets are finite.An example is the view of a CITY as, amongst other things, a collection of districts.CITY is an association of DISTRICT.

In object-oriented data modelling,all conceptual entities are modelled as objects.An abstraction representing a collection of objects with properties in common is called an object type.Objects of the same type share common *functions.The objects associated with an object type are called occurrences.* Indecomposable object types are called primitive. Decomposable objects are called composite or complex objects.A composite object is an object with a hierarchy of component object.

We have seen how complex types may be formed from primitive types using generalization,specialization,aggregation and grouping.These are the primary object-type operations in object-oriented data modelling.

Object-oriented data models support the description of both the structural and behavioural properties of a database.Structural properties concern the static organizational natural of the database. Behavioural properties are dynamic and concern the nature of possible allowable changes to the information in the database. This paper concentrates on the structural description.

In order to show more clearly how this methodology may be applied,we will concentrate on the specific recent data model which contains the abone object -oriented constructs.It is concerned almost wholly with structural properties of a database.The following is some basic concepts on OODBMS.

Object types

Atomic types are of three kinds:printable,abstract and free. A printable type corresponds to objects which may be represented directly as input or output.An abstract type corresponds to physical or conceptual objects which are not printable. Free types serve as links in generalization and specialization relationships.Non-atomic types are constructed from atomic types using aggregation and grouping as already discussed.

Functional relationships between objects

So far the ways in which complex objects may be constructed from atoms have been described.We now discuss how types may be related. A formalism is provided for representing functional relationships between types.The means by which functional relationships are represented is the fragment.

Schemas

Fragments form the building blocks of schemas.A schema is the largest unit and is a forest of fragment,poisibly connected togerther at their primary vertices by generalization and specialization edges.Thus the schema allows the representation of all the components of database model.

4.OBJECT-ORIENTED MAP DATA MODEL

It is useful to represent the three fundamental spatial object types:point ,line and polygon. These representations are based upon the definitions proposed by the national committee for Digital Cartographic Data Standards ,*which are summarized as follows:*

Point

A point is a zero-dimensional spatial object with coordinates and a unique identifier within the map;

Line

A line is a sequence of ordered points,where the beginning of the line may have a special start node and the end a special end node;

Chain

A chain is a line which is a part of one or more polygons and therefore also has a left and right polygon identifier in addition to the start and end node;

Node
A node is a junction or endpoint of one or more lines or chains;

Ring
A ring consists of one or more chains;

Polygon
A *polygon consists of one outer and zero or more inner rings;*

A map is said to be a generalization of drainage, traffic, settlement ,vegetation,soil texture,relief feature,geodetic controls feature layers and *so on.Each of these feature layers is said to be a generalization.For example* ,drainage feature is considered to be a generalization of river, lake, water well objects and so on.Each of these objects is said to be aggregation of point,line and polygon.So object-oriented map data model is abstracted into two conceptual units:logic and physical.A logic unit is a measure of map object or complex object,and a physical unit is a measure of point, line and polygon.The object-oriented map data model is showed below:

record code	point or line polygon	address pointer	descriptive pointer	parameter pointer	geo-name pointer	district pointer

record code=::{point or line or polygon number}
point or line or polygon=::{point or line or polygon identifier}

address pointer	X1Y1,X2Y2,............ XnYn

descriptive pointer	feature layer	feature class	feature quality characteristic

parameter pointer	feature width	feature depth	feature helight	feature volume	feature time	feature other

geo-name pointer	feature geo-name1	X1Y1,X2Y2 ....XnYn	feature geo-name2	X1Y1,X2Y2 ....XnYn	feature geo-name3	X1Y1,X2Y2 ....XnYn

district pointer	feature state	feature province	feature city	feature county	feature town

5.IMPLEMENTATION

The discussion up to this point has focused upon data modelling in an object-oriented setting.When the modelling is complete, there follows the implementation stage.At present,the relational systems are by far the most popular for most application.We choice standard commericial software such as ORACLE.Then the object-oriented map data model must be transformed into the relational model.It has been shown that many of the constructs discussed in this paper can be mapped to the relational model, although losing some of their natural meanning for the user and some efficiency in the process.

6.CONCLUSIONS

There is clearly a future for object-oriented techniques in many areas of computing.OODBMS is one of those areas.In particular the world of map OODBMS will benefit from further research and development of object-oriented systems ,as this seems to offer the most appropriate vehicle for handing the complexities of spatial information.The urgent needs are,on the theoretical *side,for both a formal model of object-orientation and an agreed definition* of an map OODBMS,while on the application side the need is for a successful implementation of an map OODBMS.

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Improving the international user interface in computer cartography

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ABSTRACT

As computer cartography becomes more common, the way people interact with computers to create maps is assuming a greater importance. It has long been recognized that the user interface plays an important role in the effective use of computers. An international aspect of the user interface is its cultural component. This component can be apparent in cartography in the different cartographic practices or the different ways of writing numbers between countries. However, the most serious obstacle for the acceptance and use of a computer program in another culture is language because a word-based command structure is normally used to direct the execution of a program.

Unfortunately, most computer programs for cartographic applications are developed with little consideration for their use in other countries. As a result of the importance of the software industry in the United States, English has emerged as the most common control language used in computer programs. Most existing programs for cartographic applications, even those developed for a menu-driven environment, use an English language command structure. Presently, it is at best very difficult for a person who is not familiar with the English language to create maps with the computer.

The introduction of graphical user interfaces has made the creation of less language dependent programs possible. The objective of the research is to create a more international interface for an existing computer mapping program. The use of graphical menu palettes to control the operation of the program is examined. Strategies are implemented for eliminating a large part of the language component. The major difficulty in this effort is the development of meaningful graphical symbols. It was found that words can be eliminated in most parts of the computer program through a combination of graphical symbols and a sophisticated interface. The meaning of graphical symbols that direct the program can be learned by trial and error. The cartographic or statistical concepts, however, that underlie the program - data classification, for example - need to be explained with words.

INTRODUCTION

Computers have had a great influence on cartography, particularly the process of map production. The tedious work of data preparation and drafting has been largely automated since the early 1970's. Interactive computers now assist in the map design process and small, hand-held computers are being used for the display and analysis of maps. For many, a cartography without the computer has become inconceivable.

As computers become more integrated in the production and display of maps, cartographers are now concerned with the way map-makers and map-users interact with computers. An international aspect of this problem is the cultural component of a computer program. A program is very much a reflection of its author's culture. For cartographic applications, a program's cultural component is apparent in different cartographic practices or different ways of expressing numbers. It is language, however, that is the most prominent cultural component of a computer program because a word-based command structure is normally used to direct the execution of a program. The language of a program's command structure is the major obstacle for the acceptance and use of a computer program in another culture.

As a result of initial developments in North America and the economic importance of the software industry to the United States, the English language has emerged as the most common language in computer programs. Most existing programs for cartographic applications use an English language command structure. Even programmers in other countries will often use English language commands within their programs. Presently, it is essentially impossible for a cartographer who is not familiar with the English language to create maps with the computer.

The overall objective of this research is to improve the human interface with maps by improving the user-interface with computer mapping programs. The specific objective is to create a computer mapping program that would be usable by English and non-English speakers alike. This will be accomplished by designing and implementing a more international, graphical user-interface based on icons for an existing computer mapping program. The graphical nature of cartography creates a natural link to the design of graphical user interfaces. Before proceeding, it is important to examine the concern with the user interface and the origins and advantages of the graphical user interface.

1.0 HUMAN-COMPUTER INTERACTION

The interaction between man and computer has been of concern since the advent of computers but has been of particular concern since the introduction of the microcomputer in the early 1980's (Bass 1991, Bodker 1990, Bolt 1984, Carroll 1987, Card et.al. 1983, Gardiner & Christie 1987, Hamilton et.al. 1990, Myers 1988, Norman & Draper 1986, Shneiderman 1987, Thimbly 1990). An important concept in relation to this interaction is interface. The word 'face' indicates a junction or boundary between two completely different systems. An example of a face would be the boundary between two substances that do not mix, such as oil and water. If these two substances are placed in a container, a face or boundary forms between them. Interface refers to the interaction across such a face. Interface is used to describe the set of rules and conventions by which one organized system communicates with another. The inner-workings of a computer are vastly different from the intellectual constructs of the human mind. The user interface represents the bridge between these two systems.

In the late 1960's, Alan Kay, at the Xerox Palo Alto Research Center (PARC) began to pursue a particular user interface design based on a 'desk-top' metaphor. He envisioned the computer screen as an analog to a desk that includes a variety of documents and tools to manipulate them (typewriter, calculator, etc.). Kay's research at PARC eventually produced a number of revolutionary computers including the Star. Released in the late 1970's and priced at $16,000, the Star had a bit-map display, used a hand-held pointing device called a mouse, displayed information in separate windows, and supported pop-up menus that appeared on the screen in response to a click of the mouse. The Star represented a psychologically motivated approach to the user interface, emphasizing a consistent, well-thought-through model (Smith, et.al., 1982). It has changed how we think of user interfaces.

1.1 The Graphical User Interface

The Xerox Star implemented a graphical user interface (GUI) based on icons. Although the concept of GUI dates to the early 1970's at PARC, it was not until the mid-1980's with the introduction of the Apple Macintosh that the potential of this type of interface began to be realized. The Macintosh implemented the desk-top metaphor complete with icons, windows, dialogs and the mouse. Other features of the Macintosh included a high-resolution bit-map screen and object-oriented graphics facilitating the moving and re-sizing of graphic objects (Apple 1985; Chernicoff 1985, Tagnazzini 1989). The Macintosh microcomputer has since earned the reputation for having an intuitive, easy-to-learn operating system. New operating systems for microcomputers, such as MS-Windows from Microsoft, now incorporate many Macintosh-like features such as pull-down menus, windows and dialogs.

Both the Star and the Macintosh represented major advancements in making computers easier to use. However, creating a true graphical user interface has remained an elusive goal. For example, very little of the Macintosh interface is graphical. Only the representation of the files as icons and the graphical menu palettes that are implemented by some of the programs can be construed to be graphical. The remainder of the interface is still based on words - the menu items, the text within the dialogs, etc.

The use of graphical icons in traffic signs and for international events such as the Olympics is an established practice. Research has shown that there are clear advantages to an iconic interface in computer programs. Lodding (1983) asserts that, because people find images "natural," because the human mind has powerful image memory and processing capabilities, because icons can be easily learned and recognized, and because images "can possess more universality than text," iconic interfaces can "reduce the learning curve in both time and effort, and facilitate user performance while reducing errors." Gittens (1986) verifies the ease with which graphical attributes of icons such as style and color can be used to represent common properties of a collection of objects. As early as 1970, Easterby recognized the advantages for international use of symbolic displays over those that are language-based. Figure 1 illustrates some common icons that are used in graphical design programs.

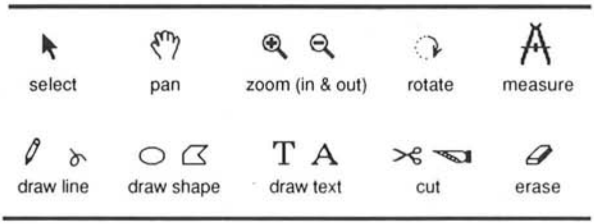

Figure 1 Icons used in graphic design programs.

The reason that computer programs still rely on words is not because of hardware or software restrictions in implementing a graphical user interface but because of a misconception that words are superior to graphics in communicating a message. We know from dealing with maps that this is not always true. This attitude is particularly apparent among programmers in North America where the dominance of the English language makes it easy to ignore the existence of other forms of communication.

1.2 Program Localization

The international aspect of the user interface has become particularly important. The overseas market for computers and programs is expanding rapidly. In 1990, for example, Apple computer earned greater than half of its revenue from international sales. As a result there is a need for software to be published in other countries. Apple Computer has responded by translating the Macintosh operating system into over 25 different languages (see Figure 2).

Arabic	French Canadian	Norwegian
British	French, Swiss	Persian
Chinese, Simplified	Greek	Portugese
Chinese, Traditional	Hebrew	Russian
Czech	Hungary	Spanish
Danish	Icelandic	Swedish
Faeroese	Italian	Thai
Finnish	Kanji	Turkish
French	Korean	Yugoslavian

Figure 2 International versions of System Software for the Apple Macintosh.

The emphasis on a word-based command structure is evident in program localization. 'Localization' refers to the process of adapting a program to a particular country or language. At one time this involved the translating of all words in the input and output sections of the source code and the subsequent re-compilation of the program. Programs are now split into so-called 'code' and 'resource forks.' The code fork is written and compiled in a traditional computer language such as C, Pascal or Fortran. This part of the program does not contain any words that would appear to the user. The resource fork, created with programs like ResEdit, contains the definition of the menus, windows and dialogs - in short, all components of a program that would need to be localized. A company interested in localizing a program will usually have a representative in a foreign country translate the menu items, window names and dialogs with a resource editing program. The source code itself is left unchanged. Figure 3 depicts the 'File' menu from the Apple Finder program in both English and German.

Figure 3 The File menu from the Apple Macintosh Finder in English and German.

Localization is normally synonymous with translation. However, there are other aspects of the program that may need to be converted as well. In many European countries, the meaning of the comma and period is reversed from what is common in North America. There are numerous ways of formatting numbers in different countries (see Figure 4). These formatting differences are usually implemented within the resource fork as well so that the source code need not be altered.

Format	Country / Region
1 234,56	French, French Canada, Finland, Norway, Portugal, Sweden
1.234,56	Denmark, Netherlands, Flemish Belgium, Germany, Iceland, Italy, Spain, Yugoslavia
1 234.56	Greece
1'234.56	Switzerland (French & German)
1,234.56	Other countries.

Figure 4 Number formats in different countries.

Other culturally specific aspects of a program that need to be localized include: 1) the formatting of monetary values; 2) the use of the proper calendar, Gregorian or one of the lunar calendars; 3) the formatting of the times of the day; 4) the proper sorting of character expressions in different languages; and 5) the use of alternate keyboards. Software is incorporated in many operating systems to handle these localization tasks (Apple Computer, 1991).

In most cases, the localization process essentially involves the translation of an English language command interface into that of another language. It is generally not a process of creating a more graphical user interface that is less dependent on words. Recognizing the ability of graphics to communicate a message, it should be possible to create a more international user interface for a computer program, particularly for a graphics-oriented computer mapping program.

2.0 A GRAPHICAL USER INTERFACE FOR CARTOGRAPHY

2.1 The Program

This research to create a more international user interface is based on a computer mapping program that has been written by the author for the Apple Macintosh computer. The program, called MacChoro, creates choropleth maps that use shadings to represent value by area. The program incorporates the Macintosh user-interface components including the use of icons, windows, menus, hierarchical menus, dialogs and the integration of the mouse as a pointing device.

Intended for the analysis of spatial data as well as the creation of maps for publication, the program integrates a spreadsheet, a variety of data classification options and the capability of creating map animations. Data is entered in the spreadsheet window and the map is displayed in the graphics and reduced-view graphics windows. Six different methods of data classification are implemented: standard deviation, equal interval, quantiles, natural breaks, user-defined ranges and an 'unclassed' option. Once the map has been defined in memory as a series of polygon objects, the depiction of a new variable or classification is accomplished in under five seconds. For viewing individual maps at a faster rate, a map animation can be created by placing a series of maps in memory as bit-map representations. These maps may depict different variables and/or different classifications of the same variable. Animation sequences can be played back at speeds up to 60 per second and are used to examine the effect of data classification or the change in the distribution of a variable over time. Animation sequences can also be saved to disk and later re-played.

Windows, menus and dialogs are the three major components of the user interface. Three separate window types are used in the program - a spreadsheet data window, a graphics window and an editor window (Figure 5). Pull-down menus contain the individual commands including the classification of the data and for the drawing of the map, legend, bar scale and neat-line. Two types of dialogs are used in the program. Option-dialogs allow user control over the various options. Within these dialogs, graphical user interface tools such as buttons, radio controls and scroll bars allow options to be specified with the mouse. Message-dialogs serve to communicate a message to the user. This can be a simple error message such as "Printer not connected" to a sophisticated concept such as "This data classification procedure is not acceptable because the data are not normally distributed."

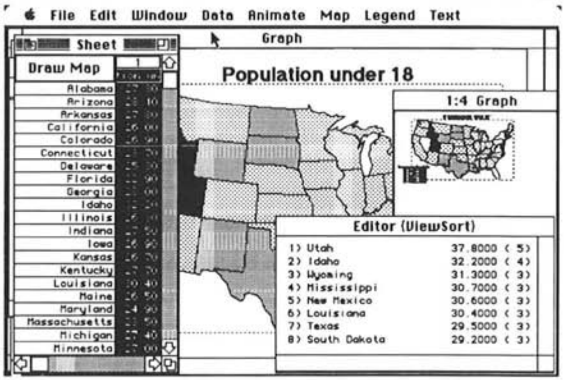

Figure 5 The Four Windows of the MacChoro Program.

2.2 Implementing a Graphical User Interface

Maps themselves implement a graphical user interface in the sense that graphical symbols are used in the place of words to communicate a message. If graphic symbols can be used on a map to communicate what is often very complex information, then surely it should be possible to use graphic symbols in a program to indicate program use and thereby create a more international user interface.

In creating a more international user interface for the MacChoro program, three aspects of the program had to be made graphical: 1) the menus; 2) the option-dialogs; and 3) the message-dialogs. The following is a description of how a graphical user interface was created for the program.

One of the first observations that was made was that the interpretation of a graphical symbol or icon is much more dependent upon surrounding symbols than words are on surrounding words. For example, with words it is possible to create a menu with a variety of dissimilar commands. A graphical menu must be more logically structured to facilitate the recognition of individual symbols. Therefore, it was not possible to simply substitute a graphical symbol for each menu item. Rather, the entire menu structure of the program had to be altered.

2.21 Converting Menus

Figure 6 depicts some of the basic icons that were developed for the program. The icons can be divided into those types that result in the drawing of a part of the map and those that control the classification of the data.[1]

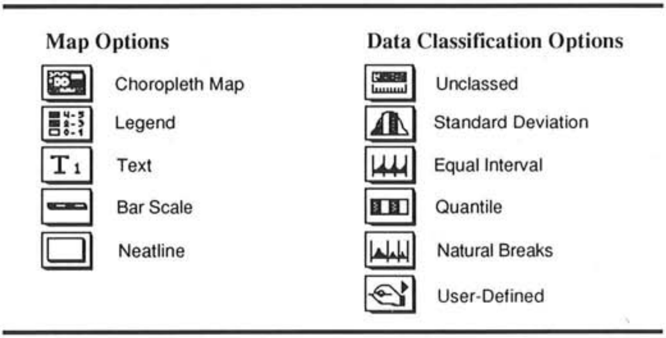

Figure 6 Palette Menus for Graphic Elements.

The original data classification menu and the corresponding palette menu are depicted in Figure 7. The palette menu includes more options at a savings of space. All possible number of classes are depicted with the addition of an update map item in the upper corner.

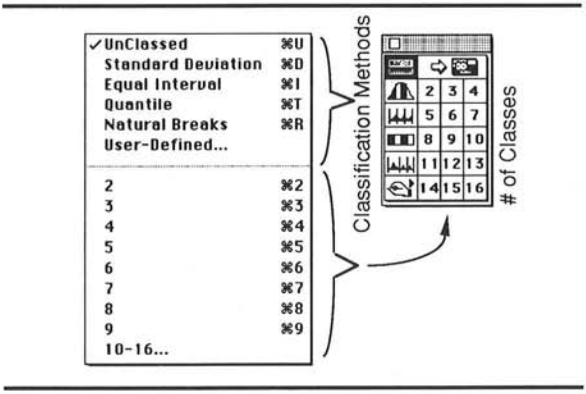

Figure 7 Text and Palette versions of the Classification Menu.

[1] The five methods of data classification: 1) Unclassed assigns a shading that is proportional to the data value (within the limitations of the display device); 2) Standard deviation classification assumes the data is normally distributed and computes class-breaks at deviations from the mean such that the normal curve will be divided into equal segments; 3) Equal interval classification divides the range of the data by the number of classes to compute the class-breaks; 4) Quantile classification method classifies the distribution so that an equal number of observations occur in each category; and 5) With the natural breaks method, the n-1 differences are computed between the ranked data values, where n is the number of classes. The class-breaks are then computed at the midpoints between the data values that correspond to the largest differences between the data values.

2.22 Converting Option Dialogs

A variety of options are associated with the depiction of some map elements. The legend, for example, may be depicted as squares, rectangles or a histogram option with the width of each shading box being proportional to the number of observations in that class. Option dialogs allow the user to select from the variety of options.

Figure 8 depicts the original text dialog and the re-designed graphic dialog that is used to control the legend display options. The type of legend desired may be selected from the upper part of the graphic dialog. Associated with the rectangle option is a scroll control to change the proportion of width to height. In a similar manner, a scroll control is associated with the histogram to change the length of the maximum histogram bar. In the lower left side of the graphic dialog are the options controlling the distance between the individual legend boxes. If the legend boxes are chosen not to be adjacent, then a scroll control can be used to alter the distance between legend boxes. The controls in the right-hand box control the distance between the legend boxes and the class-limit numbers. The lettering characteristics of the class-limit numbers may also be changed through another dialog accessed by clicking on the button below the scroll control.

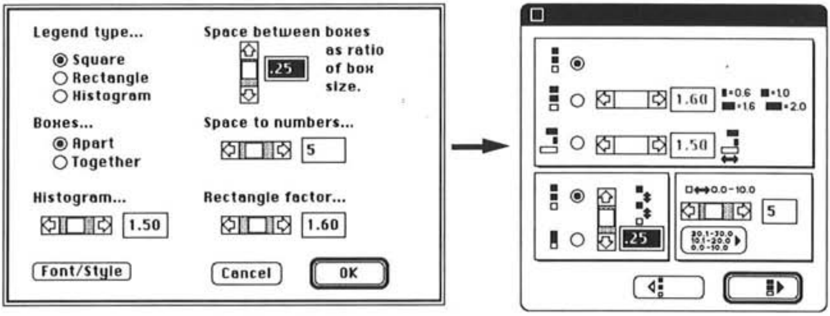

Figure 8 Text and graphical versions of the legend setup dialog.

2.23 Converting Message-Dialogs

Communicating a message with graphics is possible when the message is relatively simple. Simple 'information', 'caution' and 'stop' icons are incorporated into the Macintosh interface and can be combined with other icons to communicate a message. For example, the graphic in Figure 9 could be used to indicate that the printer is out of paper.

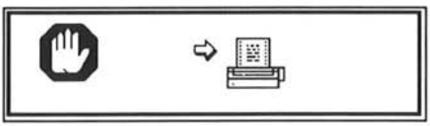

Figure 9 Graphic representation of a "Printer out of paper" message.

To communicate a concept is more difficult. For example, the standard deviation classification option used in the program expects the data to be normally distributed. If it is not, a message is presented that warns the user that the classification method is not suitable but that the values could be made more normal if they were converted to their Log base 10 equivalents (Figure 10). To understand the message completely, one needs to understand the statistical concepts involved.

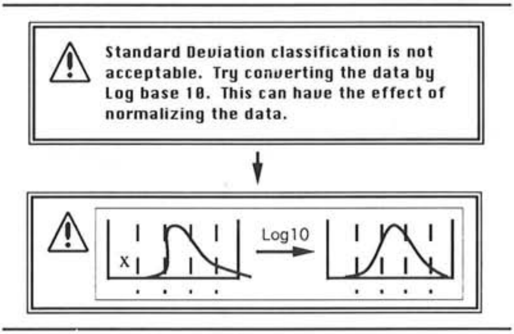

Figure 10 Text and graphic versions of a message dialog.

The best solution to the problem of communicating a message with a dialog is to write the program in such a way that such 'error' messages are not required. For example, it would be possible to check the data for normality before making the standard deviation classification an option for selection. In other words, lead the user away from mistakes before he has an opportunity to make them. In this way, you avoid the need for a dialog.

2.24 Incorporating Scripts

A script is a system of writing. Most western cultures use the Roman script. Other scripts include Chinese, Japanese, Hebrew and Arabic. Many scripts are basically alphabetic in that the characters represent discrete phonemic elements in the language. Other scripts, including Japanese Kana, are syllabic: the characters stand for syllables in the language. Still other scripts such as Japanese Kanji, Chinese, and Korean Hanja are ideographic. These do not represent pronunciation but are related to the component meanings of the words. The typical character set for such scripts are quite large, ranging from 7,000 to over 40,000 characters.

No attempt was made to incorporate different scripts in the program. Some of the icons, however, incorporate numbers in the Roman script. Although numbers in this script are generally understood, this representation might not be acceptable in many countries. Figure 11 illustrates the script used for numbers in Roman, Arabic and Farsi. The localization of the program to countries where these scripts are used would involve the re-design of the icons that contain numbers.

Roman	0	1	2	3	4	5	6	7	8	9
Arabic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩
Farsi	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹

Figure 11 The different scripts used for the representation of numbers.

3.0 CONCLUSION

The microcomputer is becoming a more standard part of our lives. Its influence on how we create and use maps will certainly be extensive. To best serve the needs of a new generation of map users both in the United States and in other countries, cartographers must be involved in the design of more international user interfaces for computer mapping programs. This particular project is an initial effort in this area.

Language can be eliminated in most aspects of a program through a combination of graphical symbols and a sophisticated interface. However, the cartographic or statistical concepts that underlie the program (data classification, for example) need to be explained with words. The meaning of graphical symbols that direct the program can often be learned by trial and error, eliminating the need for a manual. This requires the curiosity of the program user to learn program usage, often lacking in the more goal-oriented adult population.

The use of graphical symbols in a program is not without its problems. Graphical representations of objects differ between cultures. The icons for ordinary objects, such as telephones, mailboxes and traffic signs are often not the same. An icon that looks familiar to us, may be unrecognizable to someone else. Some icons may also evoke unexpected reactions in another culture and may be thought to bring bad luck or considered vulgar. The use of certain colors or even the number of objects in a group may have specific meanings. The design of iconic representations must also be approached with caution.

The most important conclusion is that the GUI has to be incorporated from the beginning. The writing of a program should begin with the interface design. This interface is then implemented in a graphic editing program where the symbols are designed and initially tested. In this way, programs can be made both easier to use and more accepted in other parts of the world.

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Visualization of quality informations as an indispensable part of optimal information extraction from a GIS

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Results of geographical analyses often lack any indication of the fitness for a certain application. This quality information is becoming indispensable in order to guide the inexperienced GIS user who is faced with an increasing amount of digitally available data. Visual support during the selection, processing, presentation and interpretation of data is considered an effective and efficient means to communicate quality information. Two projects, being performed at Utrecht University, illustrate the shifting role of cartography in the handling of spatial data quality in a GIS environment.

1. Introduction

The value of information is judged by its ability to reduce uncertainty to an acceptable level. Though simple, the above statement expresses the quintessence of the information process that describes the derivation of answers to predefined questions. Not only the answer itself, but also its correctness determines whether or not useful information has been generated.

The derivation of spatial information involves the acquisition, processing and subsequent presentation and interpretation of data that are often generalized, incomplete or even erroneous. The uncertain character of the data notwithstanding, the results of geographical analyses not infrequently lack any indication of this uncertainty, because its derivation is too cumbersome or attended by ignorance. If it is present, it is lost during the cartographic presentation of the results because of practical limitations of the map making process, and generalization. Deliberately hardening fuzzy boundaries and generalizing heterogeneous areas is generally accepted in cartography as a means to facilitate and reinforce the communication of spatial information. This lying with maps is useful as Monmonier (1991) points out, though the question rises how to map the lies that lurk in the character of spatial data? How to assess the fitness for use (Chrisman, 1984) or quality of information-to-be in order to avoid wrong interpretations and unjustified use?

After recognizing the relevance of some kind of meta-information in addition to the actual results of processing, researchers are faced with the challenge of conveying both of them in an efficient and effective way. While there are still a lot of questions to answer concerning the behaviour and propagation of errors in data, attention is shifting towards the visualization of quality and more specifically, uncertainty: stressing the truth value of the assumed "truth".

After a brief introduction to the issue of data quality, the paper focuses on the question whether or not cartography can help to optimize the information process and reduce inherent misinterpretations. Examples from existing case studies being performed at Utrecht University give an impression of the experiences gained from the derivation and use of detailed quality information.

2. Spatial Data Quality

In our attempts to understand the spatial, thematic and temporal dimensions of the phenomena that surround us, we model the geographical truth from a set of interrelated spatial data. Obviously, this implies a process of abstraction, for it is far too difficult and even undesirable to grasp the real world in its full extension, as its characteristics are subjected to the dynamics of time and space. Neither the data acquisition methods, nor men themselves can cope with such a complex reality, although the subsequent implications are quite different.
Sampling strategies underlying such techniques as remote sensing and fieldwork prove that the introduction of a certain amount of uncertainty is inevitable and related to both the nature of phenomena and the method which is used to describe them, while the intentional exclusion of data by cartographers indicates the necessity of *"seeing less to know more"*. Although the latter process is also attended by uncertainty, the skills and affinity of the map maker with the processed data happened to ensure the derivation of a reliable reflection of the geographical truth - at least with respect to the intended use of the map.
In the present paper, the uncertainties related to the data are emphasized as opposed to the inherent imperfections and deliberate generalizations of their cartographic representation.

The information process has been largely computerized as a consequence of the arrival of Geographical Information Systems (GIS), and hence the *processing of data* has been considerably facilitated and accelerated. However, this improvement does not equally hold for the *generation of information*, because the meaningful transformation of data is hampered by a number of developments:

a) the ever swelling data flow, resulting in an increasing amount of available but inaccessible data;
b) the arrival of easy-to-use GIS packages that offer a variety of alternative methods for the integration, analysis and visualization of data, without indicating the preconditions that have to be considered;
c) the increasing use of GIS by non-expert users as a result of a high degree of userfriendliness is not attended by a higher level of guidance.

In general, these developments refer to a lack of *meta-information* (see §5) or quality information to support - both in a descriptive and visual way - inexperienced users during the selection and subsequent manipulation of data within an information system. Abler (1987) refers to the need for this information by stating that:

"...without knowledge of the inaccuracies inherent in the information contained in a GIS and of the ways error can be multiplied by its most attractive capabilities, a user who makes fine distinctions will run considerable risk of making erroneous distinctions..."

The meaning of quality information is such, that it provides a user with details on the character of spatial data, enabling that user to derive - both in a direct and indirect way - a measure for the appropriateness of data for a particular application. Uncertainty, as reflected by the spatial data quality, can be specified according to five quality components, distinguished by the National Committee for Digital Cartographic Data Standards (NCDCDS, 1988):
a) lineage, describing the "pedigree" of the data, including information on

source, age and level of processing;

b) positional accuracy, indicating the extent to which the location of an object has been correctly represented;

c) attribute accuracy, indicating the correctness of a non-spatial characteristic that has been assigned to an object;

d) logical consistency, referring to the validity of relationships as embedded in the data structure;

e) completeness, referring to the relationships between a data representation (map, database) and the abstract reality which is being modelled by that representation.

The problem is twofold; information systems not only fail to offer facilities to handle data quality components, they even lack an underlying, well-defined methodological framework within which the magnitude and propagation of errors and uncertainties can be considered.
The National Center for Geographic Information and Analysis (NCGIA) in the USA dedicated one of its research initiatives to the study of errors and uncertainties in spatial databases (Initiative 1), resulting in a series of contributions to the development of such a framework (Goodchild & Gopal, 1989). More recently, Openshaw et al. (1991) have formulated five major tasks related to the study of uncertainty and error propagation within GIS, ranging from the definition of mathematical error models to the communication of uncertainty information. The latter is essential because it could mean the life-line for the justification of the research efforts in the field of data uncertainty and data quality in general. Without the support of some efficient and effective means to convey the intrinsic value of spatial data, the acceptance of quality information is doomed to failure.

3. Communication by Visualization

Visualization is increasingly identified as a valuable tool to maintain the abundance of this background information without introducing redundancy. Medyckyj-Scott (1991) states that *"...during data analysis one will require simple, throw-away visual aids in order to establish the accuracy, completeness (...) of the data, to distinguish between what is spatial pattern and spatial nonsense..."*. Visualization already plays an important role during the different stages of the information process in a decision-making environment. Armstrong et al. (1992) present a functional taxonomy of map types for a spatial decision support system; the use of these displays is closely related to a certain task, for example showing general information on the study area or enabling the assessment of differences between alternative processing results.

Within the framework of a GIS, the possibilities of visualization - according to Muehrcke (1990) referring to *"...the use of computer graphics and image processing technology in data-intensive scientific applications..."* - are also not restricted to the presentation of the final result. During an exploratory analysis, visual aids could support the selection of appropriate data while the assessment of the impact of data transformations could benefit from a visual comparison of the resulting scenarios. Present information systems nevertheless lack a cartographic interface that enables the sound communication of quality information. In the near future, however, investments in technical and conceptual developments will undoubtedly pay, under the pressure of necessity.
The NCGIA, again, touches upon the necessity of visualizing spatial data quality by

its research initiative 7; Buttenfield (1991) proposes a matrix in which the relation between the quality components and data types are established through differing graphical variables.
From this and other examples, it is believed that a lot of knowledge and techniques are readily available, though they require an adaptation to the dynamics of computer systems. The counterpart of compilation or reliability diagrams on paper maps for example (known from topographic and remotely sensed image maps) is a straightforward visualization of information related to lineage. The digital representation of uncertain (fuzzy) boundaries on a soil map even opens new perspectives, although the separate meaning of map and database in a GIS gives cause for concern. Within the scope of GIS, a map is only one of many possible reflections of the same dataset. Deriving the quality of information does not offer a license to ignore the quality of the representation itself!

In the remaining part of this paper, the use of visual quality information within a GIS is illustrated by two research projects, to wit CAMOTIUS and METAGIS. The former project is aimed at the derivation and use of uncertainty information as a means to judge the value of additional GIS data in a remote sensing classification procedure, while the latter is directed to the distinction of relevant meta-information and the development of structures and measures for its sound description and quantification respectively. The research is complementary, and reflects the fields of interest of present-day cartography at Utrecht University.

4. The CAMOTIUS Project

The importance of the different dimensions of data quality and its implications for the visualization have been discerned in the CAMOTIUS project. Initiated in the spring of 1992, this research is a joint effort of the Cartography Section at Utrecht University, the International Institute for Aerospace Survey and Earth Sciences (ITC), the Dutch National Physical Planning Agency (RPD) and Eurosense (a Belgian remote sensing firm). It is financially supported by the Netherlands Remote Sensing Board (BCRS).
CAMOTIUS[1] (van der Wel, 1992) pursues an optimal information extraction from a GIS. The extensiveness of this objective necessitates a restriction of the field of interest and therefore the project deals with the integrated use of GIS and remotely sensed data in generating and evaluating land cover classifications. Starting point is the assumption that the present-day approach of *data-driven* information processing (figure 1) will lead to considerable problems in the near future, because of reasons already mentioned (§2). The selection of data and methods is often based on practical considerations, such as the availability and accessibility of data, the costs of data and the presence or absence of a particular GIS package. Obviously, arbitrariness is not an appropriate criterion when attempting to meet the specific needs of a user. A more *product-driven* approach (figure 2) is preferred because it enables the selection of the procesing path (data, methods) that fits best within the quality requirements as defined for the pursued result.
Within the CAMOTIUS project, alternative processing paths are explored and

[1] CAMOTIUS is the Latin name of Giovanni Francesco Camoccio, a cartographer who lived in sixteenth-century Venice; more important, the name refers to an acronym, meaning: Cartography-Assisted MOnitoring - Towards an Interactive Userfriendly System.

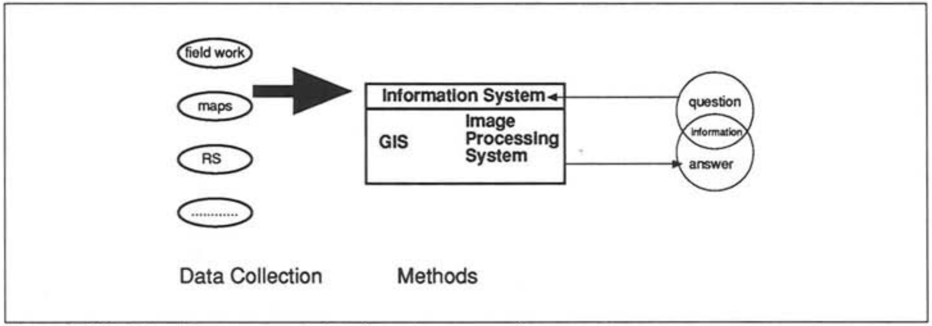

Figure 1: The data-driven approach to information processing.

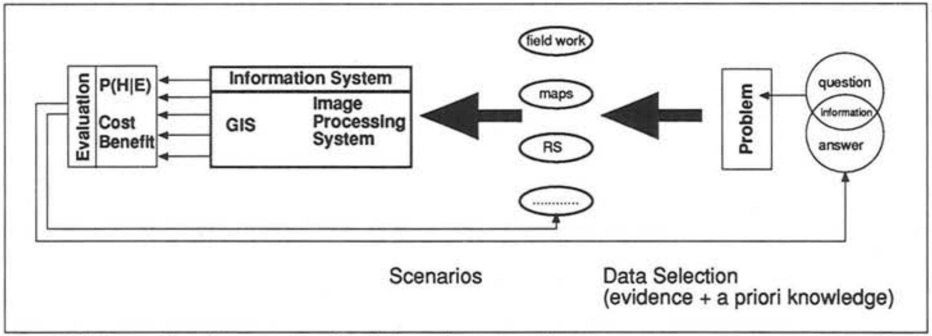

Figure 2: The product-driven approach to information processing.

evaluated by means of a cost/benefit analysis (van der Wel, 1992):

"...the value of the information provided by the selected scenario is such that its benefits offset the costs being involved in deriving and using that information in the most favourable way..."

With respect to classifications, benefits refer to correct assignments while costs relate to misclassifications (uncertainty!) as well as processing efforts. According to the product-driven approach, processing continues untill a minimum cost path of deriving information has been found - one that still meets the predefined requirements (for example, an overall accuracy level of 90%).
A prerequisite for a successful performance, however, is that sufficient quality information is derived and reported; without knowledge of the amount of uncertainty present in a dataset, a user is unable to judge the extra value of a priori knowledge in the classification procedure, as a way to reduce uncertainty. A priori knowledge can be derived from maps, aerial photographs and former classifications (different seasons or years) and even from domain experts.

Method

The classifications are based on the Maximum Likelihood method, one of the most commonly used statistical decision rules in image processing (Richards, 1986). For details, readers are referred to the remote sensing literature (see recommended readings). Here, it is sufficient to know that the method derives a *vector* of probabilities for each pixel - consisting of the class membership values - and selects the class that corresponds with the highest probability value (maximum likelihood).

In practice, image processing systems conceal the likelihood vector for the user, even the maximum likelihood **value** itself remains unknown. Of course, this is partly caused by practical limitations, for the derivation, storage and communication of complete vectors would invoke the storage computation capacities of the information system. But at the same time, it is believed that this is also an expression of the underestimation of the value of these probabilities as a measure of uncertainty. As Goodchild & Wang (1989) point out, it is worth trying to pass on the entire vector to a GIS in order to allow the system or the users to incorporate uncertainty into the analyses and results.
Commercial packages fail to provide these vectors and therefore a program has been written in Pascal to derive for each pixel the probabilities of class membership. As part of the optimization process, these data offer the possibility to monitor the effect of *a priori* knowledge on the uncertainty; but mixed pixels (mixels), heterogeneous classes and the sample integrity (training data) can be evaluated as well in this way.

The procedure will be further elucidated by discussing a number of different visualizations, that play a decisive role in the evaluation of data uncertainty (see plate 1).

Visualizations

Assume 8 land cover classes and 1 reject class ("unclassified").

1. The standard output of the CAMOTIUS software consists of a plain thematic map, that summarizes the most probable class per pixel. In addition, a bar graph can be derived showing the portion of the area that is occupied by a

particular class (as a percentage of the total area). This is the most common output, and does not reveal any serious uncertainty information, only when compared with a reference dataset.

2. For each of the 8 probability levels, an image can be created that shows the spatial distribution of their likelihoods; in this way, a maximum, second, third,..., eighth likelihood plane is generated (see plate 2). Also, each of the 8 planes can be complemented by the corresponding class information, although the significance of these alternative classes becomes questionable as the order of the likelihood plane decreases.

3. From the likelihood planes, difference images can be generated; especially the difference between maximum and second likelihood reveals valuable information concerning the reliability of class assignment, **if certain strict requirements are met**. Without going into too much detail, this means that so-called "outliers" or atypical values have to be identified. If not, high probabilities do not necessarily correspond with a high affinity of the concerning point with respect to the assumed class, but rather refer to an unreliable classification procedure based on training sets that fail to describe the distinguished classes in a representative way (Foody et al., 1992). Therefore, these values have been assigned to the reject class.
A small difference indicates that the maximum and second likelihood value differ only slightly, and hence are subjected to doubts: why select the maximum likelihood class and not the alternative (second most likely) class? One can collect more "evidence" in order to try to reduce uncertainty, thus increasing differences. The extra value of the required data can be evaluated by cost/benefit considerations. Also, one can decide to force a class assignment in the classification under consideration, and use cost/benefit analysis as a kind of "tie-breaking" process to identify the most advantageous class.

4. An optimal classification is obtained from the cost/benefit weighed differences. Questionable class assignments have been replaced by "safe" alternatives. The result is not necessarily an approximation of **the** truth (maximum truth), but the best scenario of a minimum risk classification, under the limiting conditions of the given data and classification procedure. As a tool in a decision making environment, such a classification can serve as a means to establish the possibilities and inherent value of the data under consideration for a certain application.

5. Many more products can be derived from the procedure, for instance probability images per class that provide the membership values for one specific class (see plate 2). Though not essential in the framework of the described procedure, this additional uncertainty information reveals potentially valuable spatial patterns.

6. An interesting attempt have been made to visualize data and the inherent uncertainty **in one image**. The idea is to apply a colour transformation on the classified remote sensing image, by shifting from the Red-Green-Blue system to the Intensity-Hue-Saturation system. Different hues represent the class information, while the saturation and intensity components can be used to provide uncertainty information. Middelkoop (1990) gives some nice exam-

ples of the application of this method.
A disadvantage of this method is the complexity of the resulting maps, and their decreasing readableness can seriously discourage the inexperienced GIS user / map reader.

Within the CAMOTIUS project, visualization is not only an indispensable means to handle uncertainty information, but also a way to stress the intrinsic value of spatial data in order to impress the limitations as well as perspectives of GIS on the user community.

5. The METAGIS Project

METAGIS is the preliminary name of a second research project, that investigates the development of knowledge modules to generate quality information during GIS-data analysis and manipulation. As existing methods to describe data quality are not always convenient, special attention is paid to complementary uncertainty measures to deal with incomplete information. The project is executed at the Cartography Section of Utrecht University and was initiated in 1991 with financial support of the Dutch National Physical Planning Agency.

Outline of the project

Decision making based upon spatial data analyses, which is a normal situation in a planning environment, demands a qualitatively suitable information supply which is as complete as possible. Part of this information supply is formed by the products of geographical information systems, derived by occasionally numerous manipulation phases. During manipulation of spatial data of different type, collected from different sources, it is almost inevitable that errors are introduced, leading to an unknown degree of uncertainty in the finally desired end-product. Often these products are presented without any associated estimate of their reliability or indication of the types of error they may contain (Lanter and Veregin, 1992). In addition, it can be stated that the availability of highly refined graphical representation tools supports the suggestion of high quality, because an unambiguous interpretation key is missing (Hootsmans et al., 1992). Of course, most GIS users will try the utmost to constrain errors and uncertainty in their information products to a desired minimum, but it is even more important to consider the relevance of these errors and uncertainty with respect to the desired purpose of use.

Documenting knowledge concerning data quality

The necessary knowledge to describe quality information (also indicated with "meta-information") is present in all stages of spatial data processing: during the collection of the various necessary datasets, during data storage, data preprocessing, data processing and during data presentation (not only of the final product but also during processing itself) by map, graph, diagram or just plain text. The power of meta-information is implicit in its potential user support during spatial data processing. Users, who should not necessarily be experts in every discipline of the datasets they use, can get an impression of the qualitative value of a dataset with respect to their objectives through clear user-system interfaces and, especially, the use of dynamic, graphical monitor presentations. Next to the importance of consistent digital documentation, and consequently the increased accessibility of digital spatial data, meta-information can be of high value for animation of effect simulations: what is the sensitivity of an intermediary or end product for small variations in a specific input dataset? This will provide insight in those factors that represent the larger contribution to the uncertainty and that eventually need extra attention. Possible perspective is the *reduction* of errors and uncertainty, but the first need is the ability to *describe* errors and uncertainty.

Essentially, this research is embedded in a relevant, overall quality model, that adopts elements from existing error description theories, but also introduces additional or complementary techniques to fill up gaps in existing quality description methods. At the same time, this model pays attention to the presentation of the derived quality information: how to visualize uncertainty (quality)? The theoretical framework is basically formed by a rather universal approach to the processing of spatial data, in which four primary stages are distinguished, equivalent to four stages in the processing of meta-information:

primary information	**meta-information**
collection and storage	documentation in lineage
preprocessing (physical conversion)	lineage processing
processing (conceptual conversion)	processing of thematic meta-information
presentation	visualization of meta-information

Meta-information is divided into lineage and thematic meta-information. The former refers to the physical characteristics of the dataset, the latter refers to the thematic characteristics ("content-based characteristics" in Hootsmans et al., 1992). If a physical or conceptual change in the primary information occurs, this will consequently lead to a change in lineage or in thematic meta-information, whereas in any case the method applied should be documented in the lineage of the newly derived information.

Lineage

Lanter (1991) discusses an extensive framework for the information content of lineage (see plate 3). This framework subdivides lineage in a source description frame for input layers, a command frame for intermediary products and a command frame and product frame for end-products. The source description frame contains information on name, date of acquisition, data collecting agency, projection, scale and additional characteristic features. The command frame includes the necessary GIS command(s) and parameters to derive the specific product it is attached to. The product frame describes name, use, users, responsibility and date of production of the end-product. Each frame should also describe all present parent and child links: parent links point to layers derived from this layer, child links point to layers from which this layer is derived. Through these links intermediary produced layers need not be stored (as they can be reproduced by their command frame), thus saving a large amount of storage capacity. Another advantage of parent-child links is concerned with updating of input data. If input data is updated the child-linked derived intermediary and product layers receive an out-of-date message, after which either the system or the user can decide on the necessity of updating the derived data layers.

In addition, the lineage documentation module should be capable of analyzing different methods (i.e. different command frames) to derive one specific end-product out of its input products (see plate 1): from global, small-scale, qualititative applications to detailed, large-scale, quantitative applications. The quality model applies a classification of data processing models like Burrough (1989) proposes (empirical process models, deterministic process models and stochastic process models), in which the choice for a specific process model depends on the available input data.

Thematic meta-information
Descriptive certainty measures of the attribute values in the spatial database are widely available from existing error and error propagation methods, for instance concerning digitization, interpolation, classification, resampling, vector/raster exchange, etc. These thematic certainty measures can be subdivided in positional, attribute and temporal accuracy. Thematic meta-information can consist of simply deriving a standard deviation but also of production rules that intelligently apply disciplinary knowledge (Webster et al., 1991).

Managing fuzzy knowledge in a knowledge module

A knowledge module possesses the ability to reason with the knowledge described through lineage and thematic meta-information. This is expressed by the definition of production rules that are formulated with existing Boolean logic if the necessary knowledge is completely available. If essential knowledge is lacking (reasoning with incomplete knowledge) complementary techniques should be present, like for instance the fuzzy logic measures (e.g. Robinson, 1988). Situations of reasoning with incomplete knowledge occur many times, e.g. when analogue cartographic products are used as input product by digitization. Generalization and classification in order to improve pattern analysis and interpretation cause a loss of specific information needed for quality description. With the help of fuzzy production rules derived from additional knowledge concerning the specific discipline and correlations with other, better documented datasets, much quality information appears to be hidden in a GIS.

Johnston and Hopkins (1987) make a distinction between evidential uncertainty and a-priori uncertainty, caused respectively by data uncertainty and production rule uncertainty.

Data uncertainty:

IF A THEN C
= the certainty of the conclusion (C) is dependent on the certainty of the input (A).
e.g. if $p(A)=0.65$ then $p(C)=0.65$ (if and only if the rule is assumed to be perfect).

Statements like "in this area data values possess a probability of 0.65 for being class A" assume a definite, Boolean truth value (i.e. the possibility of having a probability value 0.65 is true, the possibility of having a probability value that is not 0.65 is false). Fuzziness is introduced by adding words that express uncertainty: "a probability of being about 0.65", "a probability between 0.5 and 0.75", or just "a high probability".

Production rule uncertainty:

IF A THEN C
= the certainty of the conclusion (C) is dependent on the certainty of the rule.
e.g. if A occurs, then the occurrence of C is not self-evident (if A then p(C)=0.8)

Two theoretic examples from Boolean and fuzzy logic theory show how can be dealt with uncertainty in production rules.
Boolean possibility: poss = {0,1}
Fuzzy possibility: poss = [0..1]

Boolean logic example:

IF population density < 10 inhabitants/km2
THEN poss(class=A)=1, poss(class=not A)=0
ELSE IF population density > 100 inh/km2
THEN poss(class=C)=1, poss(class=not C)=0
ELSE poss(class=B)=1, poss(class=not B)=0

Result: if x% of the area has less than 10 inhabitants/km2 then x% of the area will be assigned class A. In other words the result will show sharp boundaries, the polygon attributes possess the same certainty value as the original input layer attribute values. A Boolean measure assumes to represent unconditional truth.

Fuzzy logic example:

IF population density is low
THEN possibility of being class A is high
ELSE IF population density is high
THEN possibility of being class C is high
ELSE possibility of being class B is high

Boundaries between low, medium and high population density are not clearly defined: each location possesses a possibility of being class A, B and C. Membership functions are defined (Burrough and Heuvelink, 1992) resulting in locations that have almost equal possibilities for two classes (see plate). This means that the boundaries in the output result will be represented by transition zones, in which uncertainty is expressed by the difference between the highest and second possibility. Arbitrarily, a certain threshold is imposed on this difference, to distinguish the zone of accepted high uncertainty and the area with an uncertainty low enough to be assigned to the class with highest possibility. An example from METAGIS is presented in plate 4. This plate shows maps in which only the uncertainty zone (of the class boundary) is visualized for different certainty threshold values as an alternative for the conventional "sharp" boundaries.

With the help of knowledge engineering theory, knowledge modules can be built that arrange available knowledge and select knowledge based upon its relevance for a certain application. A knowledge module can execute routine methods without the user's notice, depending on the explicit wish (or: knowledge level) of the user. An important task to be fulfilled by a knowledge module concerns the automated documentation of all processing methods and decisions that are encountered during processing of spatial data (Lanter, 1991). This is very important, as it enables the reproduction of intermediary and end product. This documentation is stored in the lineage info describing the result of a specific method or decision. An advantage is that the intermediary data layers between initial- and end-product are not necessarily stored as lineage describes the exact method to reproduce the end-product. Lineage offers not only the opportunity to store every step, but also wrong or less obvious methods, which generates dynamic user advise regarding alternative processing methods and routes. The idea behind this incorporates the system's ability to learn from the effect of decision taken in the past by documenting the consequences for the end-product. In a working environment where many GIS-operators should be able to produce a specific end-product, it is important to follow each user's decisions on methods and production route, because many alternatives are available, and consequently a large variation in possible end-products is very likely.

6. Concluding Remarks

Since the advent of Geographical Information Systems, spatial data processing has undergone considerable changes. The quality of data is no longer implicitly considered in the cartographic presentation that has been applied for their visualization. In a GIS, a map is just one of many possible representations of a "database reality". This conclusion is all too often used as an argument to trivialize the role of a map as a communication medium. However, the separated approach to data and presentation requires a more explicit description of data quality in order to enable a well-considered information extraction from a GIS.

Visualization has been widely accepted as an efficient and effective tool to convey quality information that can be decisive for the evaluation of a dataset. In this way, it is believed that the role of cartography is not restricted to the production of a final - map - product, but rather that cartographers can contribute to the development of a structure or framework that can serve as a starting point for the visualization of the data characteristics. By linking up quality parameters to visual variables, the latent information content of a dataset can be explored and monitored during the information process.

Visualizations, be they static or dynamic, that convince users of the appropriateness of certain data, can undoubtedly benefit from experiences gained from thematic cartography.

Acknowledgements

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fuzzy logic:

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Description of Plates

Plate 1: Outline of the CAMOTIUS procedure. At different stages, different visualizations are derived.

Plate 2: Examples from a CAMOTIUS case study being performed on a remote sensing dataset (Landsat-Thematic Mapper) of the Westland area which is characterized by a large amount of greenhouses.

Plate 3: An overview of the lineage linked data processing concept underlying the METAGIS project.

Plate 4: Visualization of fuzziness in class boundary zones. Differences between the fuzzy classes with highest and second possibility is set as measure of uncertainty. Difference values range from 0 (highly uncertain) to 1 (highly certain). Imposing different *uncertainty thresholds* results in different visualizations of the class boundary zones.

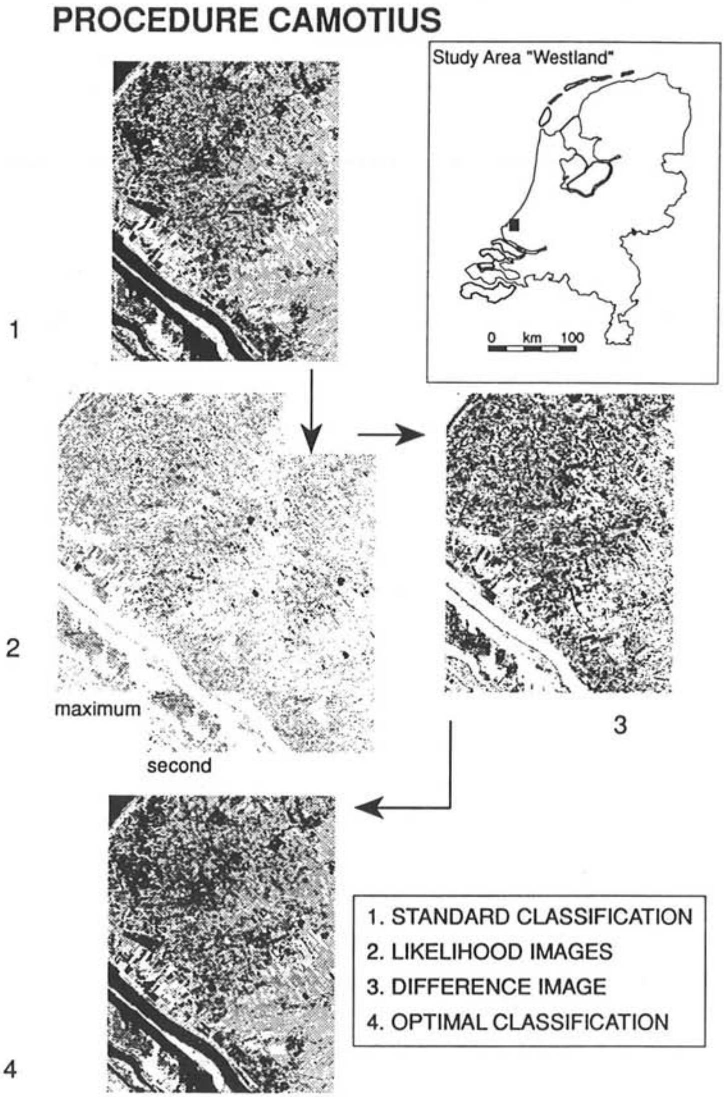

PROCEDURE CAMOTIUS
Study Area "Westland"
0 km 100
1
2
maximum
second
3
4
1. STANDARD CLASSIFICATION
2. LIKELIHOOD IMAGES
3. DIFFERENCE IMAGE
4. OPTIMAL CLASSIFICATION

Plate 1.

WESTLAND

Maximum Likelihood Values

Likelihood Values - Greenhouses

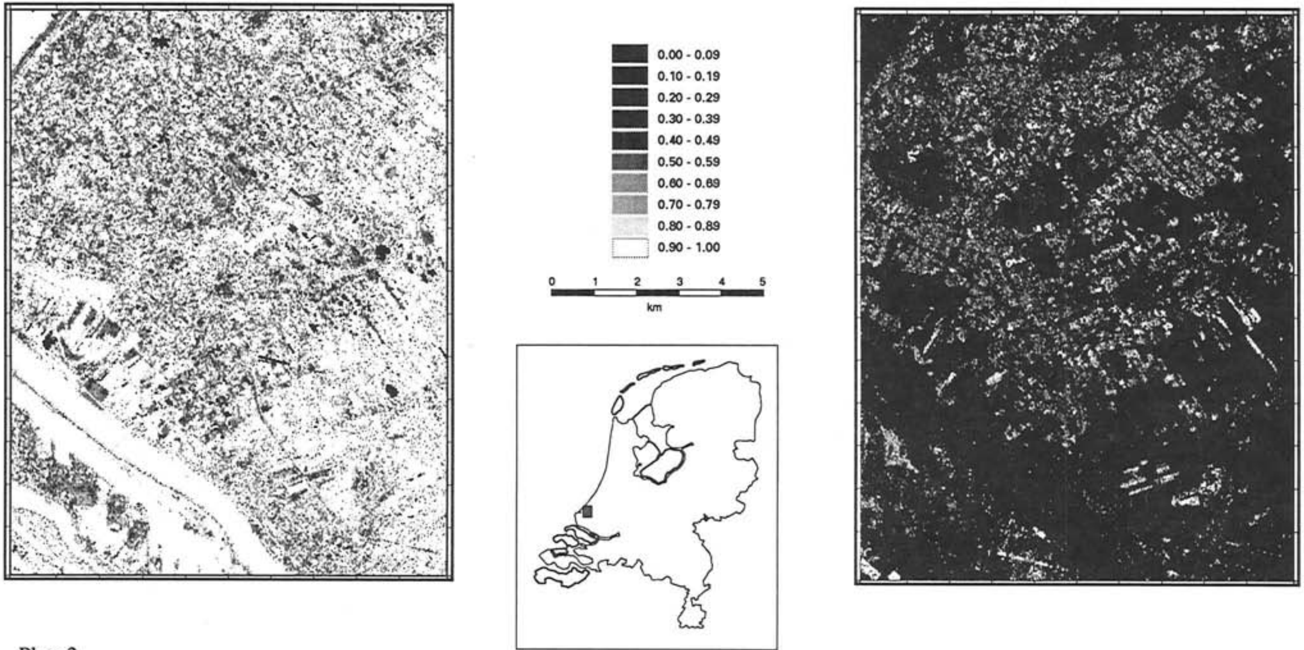
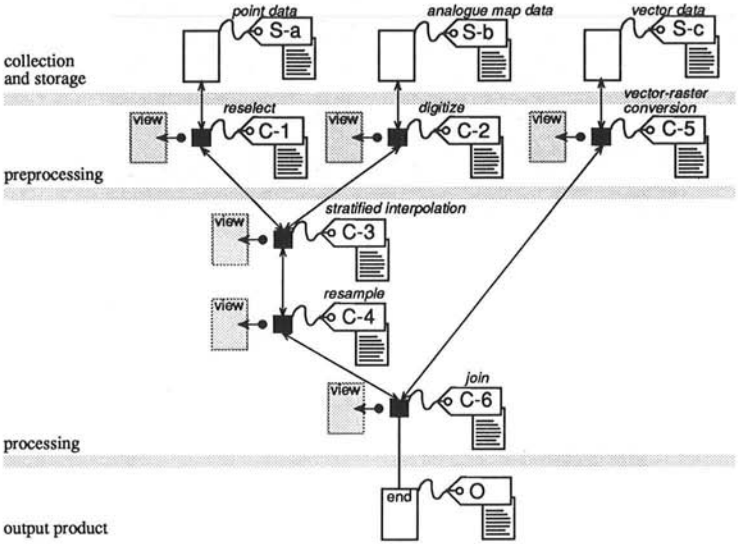


Plate 2.

Lineage linked data processing procedure in MetaGIS



Interpretation of symbols:

Lineage(after Lanter (1991), see text)

S — *Source frame* contains information on name, date of acquisition, data collecting agency, projection, scale and additional characteristic features for description.

C — *Command frame* contains the necessary GIS manipulation command(s) and corresponding parameters to derive the specific product it is attached to.

O — *Product frame* (command and output) contains the same information as a command frame, including name, use, users, responsibility, date of production.

Thematic meta-information

Quality report contains all relevant information on positional, thematic and temporal accuracy.

Object links

Parent-child link: this link points at the parent layer (from which the output is derived) and at the child layer (the layer that is derived from the input). This link is essntial for reproduction purposes and when source documents are updated. All child layers (and their child layers....) automatically receive an "out-of-date" flag, after which either the system or the user can decide on the necessity of updating the child layers.

Option button for visualization of intermediary or output product, and of lineage and thematic meta-information

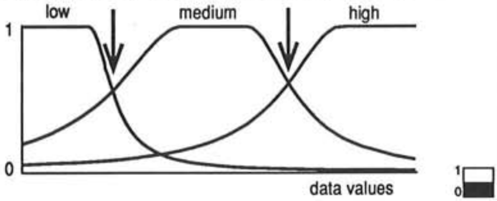
view — *Visual user interface* linked with option button

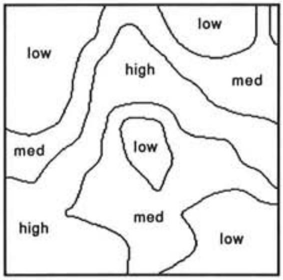
Plate 3.

Hootsmans/Van der Wel, Cartography Section, Utrecht University, Jan 1993

uncertainty threshold = 0

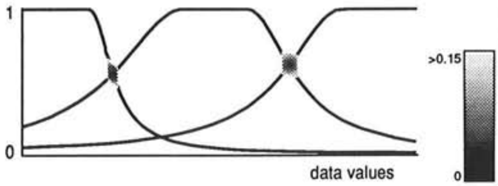
Arrows point at class boundary locations, this visualization suggests unconditional certainty of boundary locations.

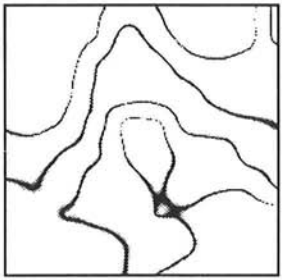




uncertainty threshold = 0.15

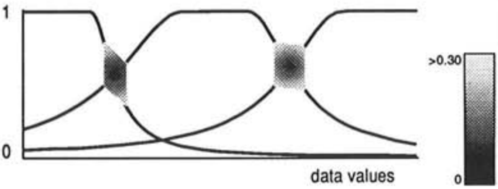
Fuzzy region in graph indicates boundary transition with a certainty of less than 0.15 (corresponding grey tones in graph and map).

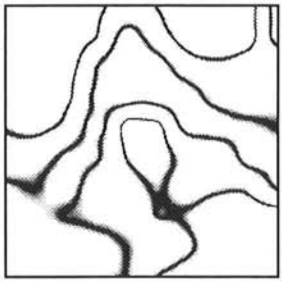




uncertainty threshold = 0.30

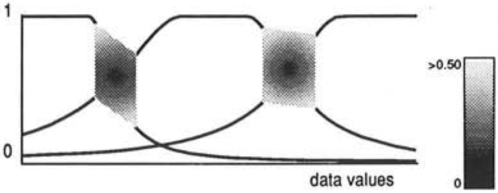
Fuzzy region in graph indicates boundary transition with a certainty of less than 0.30 (corresponding grey tones in graph and map).

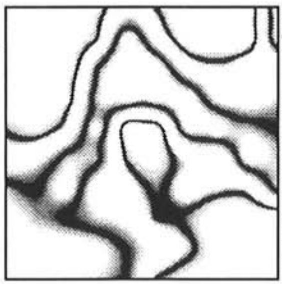




uncertainty threshold = 0.50

Fuzzy region in graph indicates boundary transition with a certainty of less than 0.50 (corresponding grey tones in graph and map).





Hootsmans/Van der Wel, Cartography Section, Utrecht University, Jan 1993

Plate 4.

Session 18

Space and Map Perception, Cartographic Design

Chairman:
V.S. Tikunov, Moscow State University (Moskva, CIS)

Topography, topology and time – the A +3T concept of geographical space in a GIS

N. Kadmon (Jerusalem, IL)

1. Introduction

The geographer, inquiringly and critically looking at the world around him, has to ask four questions concerning phenomena which arouse his attention and ours: what, where, when and why. These four W's define the envelope of our interest in the physical and human environment. However, by training the writer is a cartographer whose chief task lies in the representation and even reproduction of geographical phenomena, and he is, therefore, more involved - formally, that is - with the first three of those W's. The fourth, the highly important and perhaps dominant question of "why", he often (though, again, only formally and in theory) leaves to geographers more trained in the social and physical sciences. The main topic of this paper will thus be the analysis and definition of that space in which all geographical phenomena take place.

In order that a phenomenon can be regarded as geographical it must thus answer the three questions of *what, where* and *when*. A geographical *process* is composed of at least two geographical phenomena in which the answers to these three questions, respectively, will not be the same. In particular, the "when" must vary and relate to at least two points in time. There are geographers who base their definition of the discipline on the concept of such phenomena. But physics, astronomy and astrophysics, for example, all rely on the same three qualifiers for the definition of their particular disciplines. The difference between these fields of science and geography lies not only in the involvement of man as an active factor, but in the scale of the phenomena. The geographer's interest and treatment usually extends from the single-individual level to the global dimension - and this will be the scale of the geographical space which will be dealt with below.

2. The Cartographer and Map Space

Many definitions change with time, and the definition of cartography is no exception. At the last International Cartographic Conference held in September, 1991, in Bournemouth, England, the ICA Commission on Definitions in Cartography formulated the following. "Cartographer - a person who engages in cartography". Cartography was defined as "the discipline dealing with the conception, production, dissemination and study of maps". This, finally, required the definition of a map, which is as follows: "a conventionalised image representing selected features or characteristics of geographical reality designed for use when spatial relationships are of primary relevance". This last definition was designed, among others, to enable the inclusion of non-planar maps such as 3-D relief maps and models, tactual maps and also digital representations in a computer, even if they carry a so-called 3-D (three-dimensional) image, which really is a 2-D perspective view, in the form of a one-dimensional array. However, most maps by far are still of the flat-paper type, and the common or garden variety of cartographers, among whom the writer counts himself, has to make maps of this kind, whether in a run of a million for a tourist map or in a one-off produced as hard-copy by a PC.

Therefore, the role of the cartographer is still chiefly to transfer geographical "reality", with the aid of suitable transformations, from multi-dimensional geographical space *via* that filtered virtual (mental) space which the map author conveys to the cartographer and which serves as source space for encoding, into two-dimensional (plane) map space. And he has to do this so that the map percipient will be able to do the reverse: mentally raise this flat representation into a multi-dimensional mental image, that which Robinson and Petchenik designate the C_4-component of the communication chain, similar, as far as possible, to the cartographer's C_2 reality[1]. The problem of the map reader thus is rather like that of the two-dimensional inhabitants of Flatland in the book of this name[2].

However, because of the demands for cartographic generalization at the encoding stage which is a feature of each and every map devised by man so far, the cartographic process of "reality → map → mental image" is neither a reversible one nor is it isomorphic; the spatial mental image generated by a given map, like beauty, lies in the eye - or mind - of the beholder!

3. The Definition of Geographical Space

We usually say that we move in three-dimensional space. Disregarding air- and spacecraft, submersibles, elevators and other similar mechanical devices, our movement on the surface of the Earth is normally in two degrees of freedom (left-right and forward-back), and sometimes only in one, as in the case of a railway, even a mountain railway. Thus we must distinguish between dimensions of space and our degrees of freedom in moving in this space; only the latter are the directory variables which we can change at will.

Haggett, in "The edges of Space"[3], a paper dealing extensively with boundary conditions, describes geographical space as a structure based on the "super dimensions" of space, time and data. Each of the axes of this super space is divided into four levels of measurement: nominal, ordinal, interval and ratio. I will take up this space but develop it along somewhat different lines. These result mainly from our increasing use of the modern concept of the GIS, the geographic information system, and the fact that space and time are data, too, so that a different framework is required.

Any geographical phenomenon can be described as a vector (in the mathematical, not in the physical or graphic, sense) with components of attributes, location and time. By "attribute" we refer to the "what"-constituent of the phenomenon. Location, as we shall see in more detail later, is composed of a geometrical component and a topological one. At the present stage only a simple but characteristic example will be given. A line, such as an elevation contour in a topographic map or a block boundary in a cadastral plan, if drawn manually, can be plotted either clockwise or counter-clockwise, without any effect on the map or its use. But in a GIS, and in computer-assisted cartography in general, there is a significant difference, as will be mentioned later, and this difference is of a topological nature.

The fourth and last constituent of this supervector is time, which may be a point in time or a time interval.

Any geographical phenomenon *i* can thus be described by a vector of the general form

$$[\, a_i \,,\ g_i \,,\ p_i \,,\ t_i \,]$$

where a = geographical attributes or descriptors which may but need not be verbal descriptions of *what* (including how much of it) is dealt with;

g = geometrical location, defined e.g. by Cartesian, geocentric or polar coordinates or by rows-and-columns in one-, two- or three-dimensional Euclidean space;

p = topological descriptors such as order, contiguity or the one defining mathematical sense of a line;

t = time, as a point or interval.

In principle, the components themselves can be either scalars or vectors, or even matrices, i.e. grouped vectors. Not all of the vector positions need be filled.

<u>Geographical space can therefore be defined as the totality of vectors of the above form, ranging from individual to global scale.</u>

Measurements on each of the four axes of this superspace can, in principle, be conducted at four levels: nominal, ordinal, interval and ratio. The last two in combination can be named the quantitative level.

A geographical data base in a GIS is a subspace of the above total geographical space and must, basically, have a similar structure, again bearing in mind that not all positions must necessarily be filled. Conversely, different sub-spaces in a GIS can be combined, either scalarly or vectorially, to form a new space. In the following examples, notation is generalized and does not necessarily conform to any particular GIS practice.

A clear distinction should be made between the use of the term "vector" in the present context, where it is employed conceptually in order to portray space; and its use in the graphic representation of geographical phenomena, where it is the alternative to the raster mode. In the latter, row-and-column notation constitutes the locational framework, and attributes can be expressed as pixel contents.

4. Examples

4.1 As a basic example of a phenomenon in geographical space, let us take an elevation point.

$$[\, a_i \quad x_i \quad y_i \quad z_i \quad p_i \quad t_i \,]$$

$$[\, 12 \quad 33478 \quad 17754 \quad 174.8 \qquad\qquad]$$

12 is the attribute, in this case the code for an elevation point. x, y and z are clear. We need no explicit topological indicator here, and assume that time is irrelevant. In a GIS the location coordinates will be stored in a point image file in either vector or raster mode.

4.2 A further example would be an elevation contour line, expressed as a string of elevation points of equal altitude. Altitude can be expressed either as the (constant) metric altitude of the points, e,g, 180 m, or implied through an attribute code. 16 is here the code for a non-100m contour line. The topological indicator 1 signifies that in following the line, e.g. while digitising it, sense is so that lower points are always on the left and higher ones on the right. For a closed contour surrounding a topographic elevation feature, this code might indicate "line followed in a clockwise sense". The importance of this lies in the use made of the string of points. If, for example, area or volume (e.g. of a reservoir) is to be computed from contours, the GIS must know whether to calculate area or volume on the inside or the outside of the particular contour; in the case above, the latter might tend to infinity! Let us still assume time to be irrelevant. If $j=1,\ldots,m$ is the number of digitised points on line i, the representation of the (closed) contour will be the following matrix:

$$
\begin{array}{ccccccc}
[\,a_i & j & x_{ij} & y_{ij} & z_{ij} & p_i & t_i\,] \\
 & & & & & & \\
16 & 1 & 334786 & 177549 & 180 & 1 & \\
16 & 2 & 334791 & 177547 & 180 & 1 & \\
 & \cdot & & & & & \\
 & \cdot & & & & & \\
16 & m & x_{im} & y_{im} & 180 & 1 & \\
16 & m+1 & 334786 & 177549 & 180 & 1 &
\end{array}
$$

4.3 In a geomorphological study we might have a contour line a_1 of elevation z_0 surrounding a sand dune, expressed again as a matrix. Data are taken at time t_1 from a DTM (digital terrain model) based on a photogrammetric model. p_1 denotes following the line clockwise.

$$
\begin{array}{ccccccc}
a_1 & 1 & x_{11} & y_{11} & z_0 & p_1 & t_1 \\
\cdot & & & & & & \\
\cdot & & & & & & \\
a_1 & m & x_{1m} & y_{1m} & z_0 & p_1 & t_1 \\
a_1 & m+1 & x_{11} & y_{11} & z_0 & p_1 & t_1
\end{array}
$$

The elevations of the *identical* m points in the plane in a new DTM taken from a photogrammetric model at time t_2, shown thus (where a_2 denotes a boundary line which is no more an elevation contour, followed again in a clockwise sense):

$$
\begin{array}{ccccccc}
a_2 & 1 & x_{11} & y_{11} & z_1 & p_1 & t_2 \\
\cdot & & & & & & \\
\cdot & & & & & & \\
a_2 & m & x_{1m} & y_{1m} & z_m & p_1 & t_2 \\
a_2 & m+1 & x_{11} & y_{11} & z_1 & p_1 & t_2
\end{array}
$$

would therefore be an indication of the amount of sand transported in the time interval $t_1 \rightarrow t_2$ (the actual amount would be computed by a GIS by integration over a number of contours).

Finally, the new location, at time t_2, of the contour of original elevation z_O,

a_1	1	x_{21}	y_{21}	z_0	p_1	t_2
.						
.						
a_1	m	x_{2m}	y_{2m}	z_0	p_1	t_2
a_1	m+1	x_{21}	y_{21}	z_0	p_1	t_2

would be an indicator of dune transport, the parameters of which could be computed e.g. by

$$\frac{1}{m}\sum_{1}^{m}\sqrt{dx^2+dy^2}$$

for mean distance, and by

$$\frac{1}{m}\sum_{1}^{m}\frac{dx}{dy}$$

for mean heading or direction.

4.4 The final example will be taken from social geography. The following matrix defines part of a sub-space showing the number of white males in age group 20-40 employed in industry, in suburbs of the Pretoria Metropolitan Area, living in a house. Census areas must be described by boundary lines. These are structurally defined by a topological-hierarchical network of nodes, arcs and regions (i.e. points, lines and areas as described in para. 5.4 below). Only after this may regions be given topological indices such as a name or an ordinal number, p (Piketberg=42, Port Elizabeth=43 etc. in the example).

Vector components:

i	a_{i1} Populn group	a_{i2} Sex	a_{i3} Occupn	a_{i4} Age grp	a_{i5} Dwelling	a_{i6} No. Persns	x_i y_i z_i Geometry			p_i Topology	t_i Date
1	white	male	managrl	20-40	house	05620	–	–	–	42	12.91
2	white	male	managrl	20-40	house	92194	–	–	–	43	12.91
.											
.											

Coded numerical data:

1	1	0	10	5	01	05620	.	.	.	42	12.91
2	1	0	10	5	01	92194	.	.	.	43	12.91
.											
.											

In a GIS these data will be recorded in an attribute file; the topological indicators can then be used to link attributes with the respective geometry.

5. The Four Axes of Geographical Space

If space is defined by a 4-component supervector, one can regard it as 4-dimensional and having four axes. Each of these axes will now be briefly and separately dealt with.

5.1 The A-Axis

Measurements of attributes can be on all four levels - nominal, ordinal, interval and ratio. Often, as in the last example above, numerical codes are substituted for nominal, e.g. verbal, designations. Quantitative attribute surfaces can be continuous, as in the case of rainfall or barometric pressure (although *senso stricto* the latter is not even defined at a point!). They can also be discontinuous, for example when expressed as a series of choropleths. The geographical variable itself, however (not to be confused with the surface it generates in space) can be continuous in both cases (e.g. temperature, a continuous variable with a continuous surface, as against density of population by districts, a continuous variable with a discontinuous choropleth surface). Isolines in a map of a continuous variable should logically not be regarded simply as connecting a series of points of equal value, but as the intersections, projected onto base level, between equipotential or equal-value surfaces and the attribute surface of (usually) double curvature.

5.2 The G-Axis

Measurement of "geometric" location, too, can be on all levels. Thus, in a plane map, depending on the measure of precision required, location can be described e.g. by map sheet name (nominal), by map square such as 14F, by row-and-column (ordinal and always integer) or by coordinates in real or floating-point format, whether geocentric (lat., long.), plane topographic-Cartesian (x,y) or polar (ϱ,θ).

Latitude and longitude, which we shall meet again later, are an interesting mixture. Plane topographic coordinates (e.g. the UTM grid) usually have equal units on both axes. Geographical latitude is measured on a ratio scale, its true origin being always the physically and intrinsically-defined equator. Longitude, on the other hand, does not have a true zero; among others, Potsdam, Paris, Moscow and, up to about WW I, the Canaries Island of Ferro - introduced 20 centuries ago by the Greeks - have been used for establishing prime meridians, as well as Greenwich. Longitude is therefore measured on an interval scale. This indeterminacy may have led A.A. Milne's Christopher Robin to inform Winnie-the-Pooh - who, on finding the north "pole", asked whether there were other poles to discover - that "there is a South Pole, and I believe there is an East Pole and a West Pole, but people don't like to talk about them"[4].

5.3 The P-Axis

Topology deals chiefly with three elements: nodes, arcs and regions, and a subsidiary one, islands within regions. In geometry these are represented by points, lines and areas. This branch of mathematics is concerned with those relations between these elements which are invariant under changes in geometry. This is the reason why topology has been described as "geometry on a rubber sheet". Certain topological expressions such as adjacency, incidence and even right and left are required in expressing relations between geographical units in space, as well as in a GIS and its data base representing space. Topological methods are particularly suitable for dealing with networks of all

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kinds. Thus, one of the tests for consistency, applicable also in a GIS, is provided by Euler's law which states that

$$n - a + r = q - h + 1$$

where

n = Number of nodes
a = " " arcs
r = " " regions
q = " " unconnected regions
h = " " enclaves ("windows")

It should be added that in topology a region can be of the closed type, represented in geometry by a closed polygon; or open, i.e. unbounded. In practice, the latter type does not occur in a GIS, where any data base is finite and bounded, e.g. by a tile or a map series.

A geographical space, subdivided into smaller areas and perhaps including enclaves and exclaves, can be expressed as a network of nodes, arcs and regions. The structural base in the GIS will be the geometry of the nodes, i.e. their coordinates. But in order to define the boundaries between regions, as well as the regions themselves, the (topological) characteristic of direction of an arc (or line) between each pair of nodes (or points) must be defined, whether towards or away from a specific node. This requirement results in the necessity of specifying the order of points along any line to be processed, and the order of any lines used to make up a polygon - well-known to those who operate with a GIS. The result is a so-called incidence matrix. The German term Weg-Matrix better expresses the facility of finding, among others, least-distance paths (where "distance" can mean non-metric variables such as time distance (Gatrell, 1983[5]) or societal ones (Sack, 1980[6]). Regions can then be named or numbered after being defined by the topological designation of the arcs surrounding them, the latter being anchored in space via the geometry of their end nodes. Any single attribute relating to a region, such as density of population, can then be assigned – topologically – to any point within this region, not being tied anymore to geometry.

5.4 The T-Axis

Time is not running out. If anything is, we are - out of it. Time and the T-axis are fixed, at least in geographical space if not in relativity space or in some of the paraspaces described e.g. by Sack (1980[7]). It can be measured, as points in time or as time intervals, on an ordinal scale ("before, now, after") or on a quantitative one, with a clock and a calendar. Since every person can set his or her watch and regulate his or her personal life according to a particular calendar - solar (e.g. Christian), lunar (Moslem) or luno-solar (Jewish), or even calculate time from the big bang, it is clear that time will be measured on an interval scale and not on a ratio scale.

Measuring time on a linear scale poses no particular problems; measuring simultaneity does. We shall here bypass questions such as what is meant by an event occurring simultaneously in two distant places, following some cultures, inter alia that of the Hopi Indians, for whom such a questions has no meaning - and therefore requires no answer (Tuan, 1977[8]). However, being concerned with measuring and recording both time and geometric location, a few words will be added on the interaction between the two.

6. Time↔Geometry Interaction in Geography

There has always been a strong link between the time factor and geometrical location. Measuring location is always a matter of measuring time. The ancient Greeks measured latitude by the length of the longest day in the year - a method which automatically defines the equator, both as an abstract concept and as a concrete line in a map. Only later was angular measure introduced; in certain A-edition incunabulae of Ptolemy's "Geographica" both methods are used side-by-side.

To an even greater extent, determination of *longitude* consists of a measurement of time, from antiquity, through Harrison's chronometer to the radio signals of the present. Here, too, as in latitude, angular measure and units replaced temporal ones, but retained time terminology: we measure small angles in minutes and seconds (of arc).

Triangulation is being replaced by trilateration and, in general, by direct measurement of distance with electro-optical instruments. These measure neither distance nor time, but differences in phase of transmitted and returning coherent waves, these differences being a function of both. In the latest and most prevalent method of measuring location, namely GPS (global positioning systems), the phase shift between locally generated and the incoming "square" waves of known linear velocity from at least three satellites, depending on time of transit of the message, is converted into time and thus into distance. The position error envelope, too, is defined by time.

Two further remarks on terminology might be added. Whereas location is measured with the aid of time, and small angles are recorded in time terminology, the "passage" of time itself, or rather the passage along the time axis, is usually described as length (of time), which normally denotes distance. And in many astronomical applications distance, i.e. length, is measured in terms (though not in units) of time: light-years. These few examples supply a fair indication of the close and intricate relations between time and geometrical space.

Time has perhaps a greater influence on, and importance in, our everyday lives than any other factor - from music, through fixing a date with a partner (which requires coordinates of both time and location) to economics and finance. Just try not to return a loan on time, be late for a date or listen to a violinist not generating the correct number of vibrations per unit of time....

7. Conclusion

So, to conclude: geographical space can be defined as the totality of vectors of the form

$$[\, a_i\,,\ g_i\,,\ p_i\,,\ t_i \,]$$

from individual to global level.

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The perception of the representation of temporal change in choropleth maps for visually handicapped people

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ABSTRACT

Several strategies exist to represent spatio-temporal changes in maps, both in a static and in a dynamic way. Those visually handicapped people who are predominantly depending on tactual perception of maps (still) have to rely on static representations, either through single or multiple maps. Given the constraints in the perception and processing of tactual information, even with a single map, the question arises, however, whether severely visually handicapped people are able to 'conveniently' use multiple maps. In the exploratory study described here, this question has been dealt with. Tests have been performed using choropleth maps on swell paper. Questions were asked at three distinct reading levels. Result show that the patterns developed were clearly dinstinguishable and evoking the required ordered perception. In the map reading tasks, the criteria set for convenient use were met for all except one of the questions.

INTRODUCTION

Spatial patterns are seldom static. All kinds of dynamic processes influence and alter patterns and relationships in man's social and physical environment. Nowadays, with techniques such as remote sensing and the use of GISs, enormous amounts of spatio-temporal data can be gathered and handled. Representation of these data can be useful for the analysis and monitoring of spatial processes, and may facilitate planning. It is not surprising, therefore, that mapping of dynamics is nowadays receiving substantial attention in cartographic literature (see e.g. Kraak, 1992[6], Langran, 1992[7], Slocum, and Egbert, 1991[13]).

Common strategies to represent spatio-temporal data include single static displays, multiple static displays and dynamic (animated) visualizations. In a single static display, the dynamic aspects are incorporated in the data and graphically represented in a single map. A multiple static strategy uses two or more maps, each showing the status of an area at another moment in time. It forces the user to make (usually sequential) comparisons between maps to understand temporal aspects. In a dynamic display, the evolution of a pattern can be observed through temporally sequenced changes in the image (Monmonier, 1990[9]).

These days, computer generated animated visualizations are receiving much attention, because they allow the cartographer to actually represent changing patterns in a dynamic way (see e.g. DiBiase, 1991[4], Fairbairn and Deeley, 1991[5]). Unfortunately for visually handicapped people, these dynamic displays are, as many other types of maps, not (yet?) available in a tactual format. However, if better integration of this growing group of people in society is required, access to maps, including those showing temporal changes, is required. This would, for example, offer possibilities to participate in procedures where planning decisions are taken and, in general, allow better understanding of spatial dynamics, which is required to understand many topics dealt with in education. Currently, visually handicapped people have to rely on static representations of temporal change. Whether single or multiple static displays are most suitable depends on the data to be represented and on the purpose of the map. Therefore, it would be good to have both strategies in principle available.

Given the constraints in the perception and processing of tactual information, even from a single map, the question arises, however, whether visually handicapped people are able to conveniently use multiple static displays. Constraints which influence map reading in general stem from the fact that the sensors used for tactual perception are more restricted in resolution and speed by which symbols can be detected than the eyes. Also, people relying on tactual perception have to mentally construct the total image presented in a map by sequential perception and processing of bits and pieces. There is no immediate appreciation of the size of the map, the position of mapface, legend and other marginal items, nor of the organization of elements in the map and the type and density of symbols (Castner, 1983[3]). In case of multiple map use, (part of) the constructed image of one map has to be stored in memory to allow subsequent comparison with (parts of) one or more other mentally constructed images.

This paper addresses the question whether the multiple static strategy can be applied for people with a severe visual handicap: those with at best 10% residual vision, who are predominantly depending on tactual perception of written text and images. Given the perception constraints mentioned above, problems with respect to the accuracy of the answers and response times are expected to increase rapidly with increasing complexity of the comparisons that have to be made. The study was only exploratory, meant to attain some insight in the possibility to use multiple maps. If the accuracy of the answers and the response time would allow so, further studies could be conducted to gain more insight. Accuracy was considered to be the most important measure. Although response time has also been registered, it has only been used to see whether the required time spans were 'reasonable'.

METHOD

Spatial dynamics may result from changes in the locational, the qualitative or quantitative characteristics of phenomena over time, or from a combination of these aspects. Most frequently (although not exclusively) thematic maps are used to obtain information on spatial dynamics. Because a lot of effort is still required in the field of thematic mapping for visually handicapped people, it was decided to use a thematic map type for testing. In order to avoid confusion, both with the map user and in interpreting the results, this exploratory study concentrates on choropleth maps, in which, it was assumed, only the quantitative characteristics would change over time, no changes in administrative boundaries were incorporated.

Tactual perception strongly depends on deformation of the finger skin. In a map reading situation, the degree and speed of deformation is mainly influenced by the tactual variables height, sharpness and texture (Barth, 1982[1], Lederman and Kinch, 1979[8], Schiff, 1982[12]). If symbols vary in elevation, height is applied. Sharpness refers to the edges of elevated symbols, sharp symbols have vertical edges, other symbols show a more gradual transition to the base. Texture refers to the degree of coarseness or roughness that can be felt. The variables mentioned above are all supposed to allow ordered perception (Bertin, 1974[2]), so in principle they could be applied in choropleth maps.

Symbols and maps were to be developed on micro-capsule or swell paper. The material is extensively used in educational institutes, because it can be easily and relatively cheaply produced at decentralized locations. An additional advantage is that point, line, area symbols and text are not only expanded, they also appear in black on the light background of the material. The high contrast allows low vision people to make use of several senses to extract information. A limitation compared to maps in thermoformed plastic, however, is that the possibility to obtain variations in sharpness and height is more restricted. Therefore, texture has been chosen for the test maps. Since the expended image is also appearing in black on the map, the patterns to be used should tactually and visually allow ordered perception. Furthermore, the importance of creating enough contrast was considered in the design stage.

After the design of the patterns, four maps were developed, one training map, showing population density in a fictitious area in 1975, and three test maps, showing population density in resp. 1970, 1980 and 1990 for another fictitious area, with other values attached to the symbols (figure 1-3). The maps had to fit on A4 swell paper sheets. Big maps should, if possible, be avoided for visually handicapped people, because integration of different parts of the map into one mental image is a difficult task. Therefore, it is recommended not to exceed a width of two hand spans (approx. 30 cm for adults), sothat the map at least can be scanned in one movement from top to bottom (Wiedel and Groves, 1970[14]). The mapped areas, used in the test were smaller (18 x 15 cm), hence possible reading difficulties would not stem from the size of the maps. It was decided that the test maps should contain all the information which is required for a normal map reading task. Therefore, next to area patterns, braille codes were used for reference and line symbols to show area boundaries. Furthermore, the maps contained a title and, on a separate small sheet, but attached to the map, a legend and scale bar (figure 4). Depending on the patterns used, area symbols are usually legible if length and width are at least 2 cm (Nolan and Morris, 1971[11]). However, since braille codes were added, the dimensions of the smallest area on the test maps were larger (3.4 and 4 cm). A symbol separation of at least 2 mm was applied in order to increase legibility. On the three maps, values were assigned to the areas in such a way, that each area showed a different development, e.g. constant density, in- or decrease in both decades, constant density in one decade and in- or decrease in the other, etc.

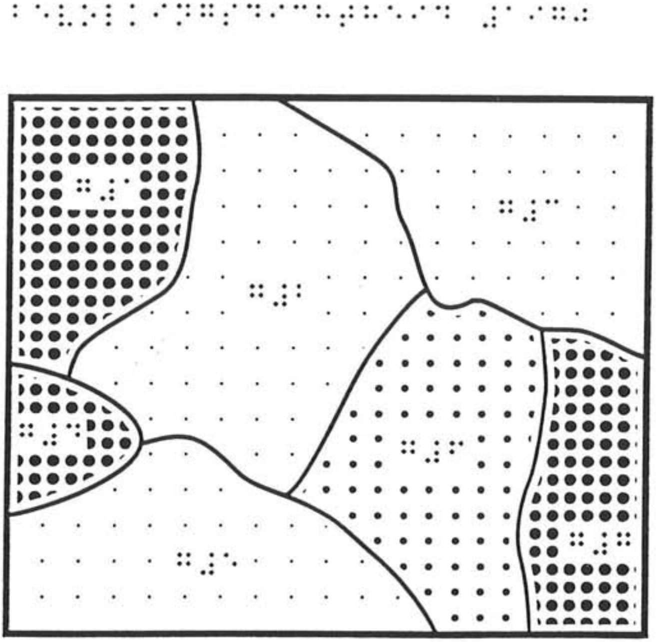

Figure 1
Population density 1970,
map used in test no.3 *)

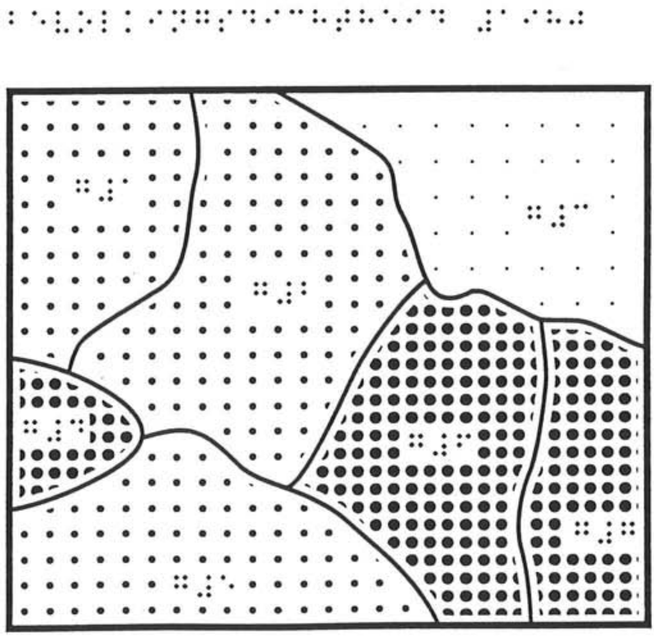

Figure 2
Population density 1980,
map used in test no.3 *)

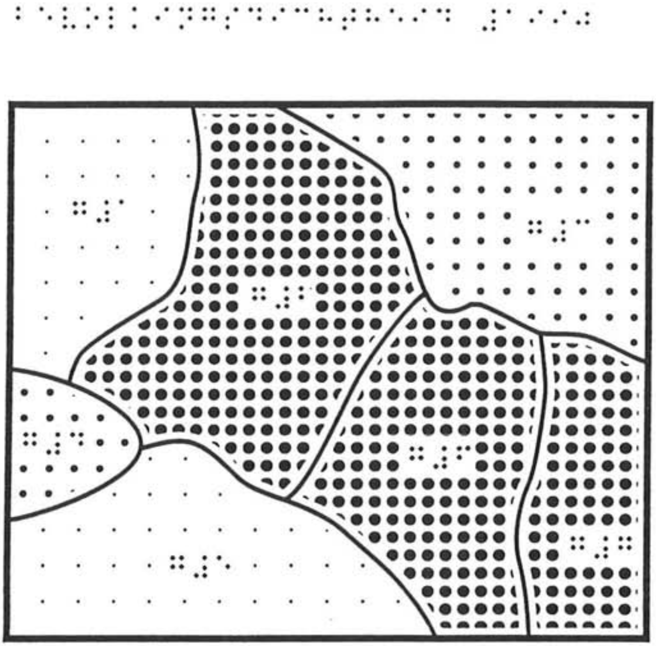

Figure 3
Population density 1990,
map used in test no.3 *)

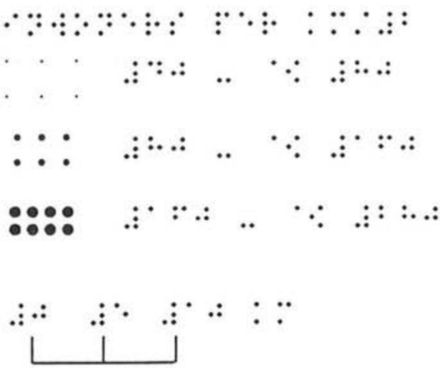

Figure 4
Legend of the maps used in test no.3 *)

*) Illustrations of test materials have been reduced to app. 48%

Each subject was individually tested, and oral explanation was given in advance. Three tests were conducted. The aim of test no.1 was to determine the ability of the subjects to tactually discriminate the symbols from each other. Each symbol appeared as a 5 x 5 cm area on an A5-sized sheet. The subjects had to perform a paired comparison test. In total, nine pairs of symbols were presented: each symbol combined with the other symbols and with its equivalent, for both hands.

Test no.2 was performed in order to see whether those symbols would allow spontaneous and unambigious ranking. The three patterns were presented and subjects were asked to rank them in a descending order. After that, the participants were allowed to explore the training map. This step was included in order to obtain a first impression of a subject's ability to read a choropleth map and to accustom him to the final test. Response was not recorded.

The purpose of test no.3 was to assess whether multiple static choropleth maps can be conveniently used to perceive changes in population density. Perception was considered to be convenient if the rather rigid criterion of at least 75% correct response to the questions was met. In addition, response time was observed, but only to see whether users were able to answer within 'reasonable' time spans. The criterion of 75% has been chosen to partly compensate for the fact that in this preliminary study all subjects were highest level primary school or secondary school students. These students are regularly confronted with graphic displays (although not necessarily maps), and in this respect perhaps not forming a representative sample of the visually severely handicapped population. They belong, however, to the biggest potential group of users of images showing (spatial) dynamics. In test no.3 questions were asked at the following reading levels: elementary, intermediate and overall level, in which subjects had to deal with respectively one element, a group of elements and all elements or the total pattern represented in the map(s) (Bertin, 1974[2]). Figure 5 lists the questions for each level. The subdivisions in A and B levels refer to the number of areas/maps, that were involved in the comparisons. At B level more comparisons had to be made. The more pragmatic sequence in which questions were asked has also been indicated by the question numbers. Both simultaneous and sequential exploration of the maps was incorporated. The 1970 map was first presented to the subjects. They were allowed to only read the legend. After that, a finger was laid on the starting point (the smallest area, no.4), then questions started. Subjects had to find other areas themselves. After question 10 had been asked, the developments in area 4 in the periods 1970-1980-1990 were described as an example in order to prepare subjects for questions 12 and 14.

SUBJECTS

The subjects for this study had to be representatives of the potential user group of displays which show dynamics, such as scientists and school children. Nowadays in The Netherlands, these children are usually attending regular schools, relatively few people attend classes at special institutes for visually handicapped people. Therefore,

Reading level	Question no.	Map(s) used	Question
I elementary	1	1970	What is the density in area 4?
	3	1970	Which area has a low density (one is enough)?
	4	1980	What is the density in area 4?
	8	1980	Which area has the lowest density?
	10	1990	What is the density in area 4?
IIA intermediate 2 comparisons	2	1970	Has the area North of it the same, a higher or lower density?
	5	1970/80	Was the density in 1970 equal, higher or lower?
	6	1980	Has the area North of area 4 the same, a higher or lower density?
	7	1970/80	Was the density of this area in 1970 equal, higher or lower?
	9	1970/80	Was the density of this area in 1970 equal, higher or lower?
	11	1990	Has the area North of area 4 the same, a higher or lower density?
	13	1990	Which area has the same density?
IIB intermediate 3 comparisons	12	1970/80/90	Describe the developments of this area in the period 1970-1980-1990.
	14	1970/80/90	Describe the developments of this area in the period 1970-1980-1990.
IIIA overall 1 map	15	1970	Describe the pattern of the map. Concentrate on the areas with the highest density.
	16	1980	Describe the pattern of the map. Concentrate on the areas with the highest density.
	18	1990	Describe the pattern of the map. Concentrate on the areas with the highest density.
IIIB overall 2 maps	17	1970/80	What differences occurred in the most densily populated areas?
	19	1980/90	What differences occurred in the most densily populated areas?

Figure 5 - Questions used in test no. 3 per reading level.

Characteristic	Absolute no.	Percentage
Sex:		
male	10	55.6
female	8	44.4
Age:		
11-14 years	2	11.1
15-18 years	12	66.7
19-22 years	4	22.2
Education:		
elementary school and lower vocational training	8	44.4
higher than lower vocational training	10	55.6
Visual handicap:		
0 - <5% vision (blind)		
from age of ≤ 6 years	9	50.0
from age of > 6 years	1	5.6
5 - < 10% vision		
from age of ≤ 6 years	5	27.8
from age of > 6 years	3	16.7
Perception:		
tactual	14	77.8
tactual and visual	4	22.2
Mobility training:		
occasionally with maps	8	44.4
without maps	9	50.0
no training	1	5.6

Figure 6 - Main characteristics of the 18 subjects.

they are widely dispersed over space. For pragmatic reasons, however, subjects who were living in a few, more or less concentrated areas had to be found. It was decided to use highest level primary or secondary school students. Further requirements were: at best 10% residual vision, braille reading, normally learning, some previous experience with graphic displays on swell paper and understanding of the concept 'population density'. The subjects were approached through educational institutes. Their main characteristics are summarized in figure 6. Of the 4 persons who also used vision for the tasks, one was almost purely relying on tactual perception, 2 were mainly using vision and one person indicated that he used both senses equally. The majority of the subjects was congenitally visually handicapped. According to some authors previous visual experience, provided it was gained after the age of 6 years old, would facilitate map use. However, no consensus about this exists.

RESULTS

In the paired comparison test, only one error could be registered: the identical symbols which were later supposed to represent the lowest density were once perceived as 'different'. Three people initially had some doubts about the identical patterns for medium density, but each of them finally decided that the patterns were similar. The fact that error and doubts only occurred with identical patterns can perhaps be explained from the fact that subjects were searching for minor differences, which were not existing.

In the ranking test, no mistakes were made at all. Moreover, subjects were able to rank the patterns very quickly, and without any doubt. It seems, therefore, that the symbols evoke the intended ordered perception.

Figure 7 shows the correctness of the responses to the questions in test no.3. The number of incorrect and missing reponses seems much lower than perhaps could have been expected, given the perception constraints; 94,2% of all answers was correct. Six questions obtained a score of 100% correct, and all questions except no. 19 met the severe criterion of 75% correct response. The incorrect answers to this question all stem from the fact that the subjects dit not mention the decrease in population density in the smallest area (no.4) for the period 1980-1990. Further evidence of perception problems with area 4 came from the analysis of all incorrect answers: 13 errors (81.3% of all cases) resulted from perception problems with this area. Several reasons can be thought of to explain the difficulty. The most obvious one seems that the area was too small, and interference occurred with the braille code inside. In addition, the fact that this small area was a marginal one may have contributed to the incorrect answers to question 19.

It has been expected that the percentage of correct answers would decrease with increasing reading level. There indeed is an increase from level II to level III. No increase occurs, however, from level I to level II. Response to level IIB questions even obtained a score of 100% correct. At this level, no comparisons had to be made

Reading level	Question no.	No response	Incorrect answers	Correct answers absolute	relative (%)
I	1	-	1	17	94.4
	3	-	-	18	100.0
	4	-	2	16	88.9
	8	-	1	17	94.4
	10	-	1	17	94.4
Subtotal	-	0	5	85	94.4
IIA	2	-	1	17	94.4
	5	-	-	18	100.0
	6	-	1	17	94.4
	7	-	-	18	100.0
	9	-	1	17	94.4
	11	-	1	17	94.4
	13	-	-	18	100.0
Subtotal	-	0	4	122	96.8
IIB	12	-	-	18	100.0
	14	-	-	18	100.0
Subtotal	-	0	0	36	100.0
IIIA	15	-	2	16	88.9
	16	1	1	16	88.9
	18	1	-	17	94.4
Subtotal	-	2	3	49	90.7
IIIB	17	1	-	17	94.4
	19	1	4	13	72.2
Subtotal	-	2	4	30	83.3
Grandtotal	-	4	16	322	94.2

Figure 7 - Type of response to questions in test no. 3.

Reading level	Question no.	Average response time (sec.)	Standard deviation
I	1 3 4 8 10	10.6 7.1 7.6 8.6 8.9	8.0 4.8 5.9 12.3 6.2
Type 1 question	-	8.5	7.8
IIA	2 5 6 7 9 11 13	7.1 5.8 8.7 12.8 8.6 8.1 8.6	6.4 6.6 7.7 19.6 14.1 3.8 5.9
Type IIA question	-	8.5	10.5
IIB	12 14	19.3 16.5	12.1 8.9
Type IIB question	-	18.0	10.6
IIIA	15 16 18	25.3 18.6 19.8	17.3 13.9 17.0
Type IIIA question	-	21.3	16.1
IIIB	17 19	32.4 25.3	19.5 14.9
Type IIIB question	-	28.8	17.5

Figure 8 - Response time in test no. 3.

in which area 4 was involved.

Analysis of the response in relation to the subjects reveals that 10 subjects (55.6%) obtained a score of 100% correct answers. Only 3 subjects made more than 1 error or gave no response. Their answers were resp. 3,6 and 6 times not correct. One of these persons was mainly reading visually, at a reading distance of appr. 10 cm. His mistakes were all related to area 4, which he perceive as area with 80-<160 inhabitants per km^2. It seems likely that he was focussing on the braille code inside the area. The size of the braille dots is most similar to the pattern which represents 80-<160 inhabitants per km^2. The subject only made this mistake in area 4, not in other, larger areas, which again contributes to the assumption that area 4 was too small in this test. The youngest subject had a score of 6 answers not correct. This highest level primary school student has least experience, and her scanning technique clearly needs improvement. The other subject with 6 answers not correct was a poor reader. It was difficult for him to make comparisons among maps, because he moved the maps all the time in several directions. His scanning technique was poor, and he had to be remembered several times that he could always refer to the legend in order to find an answer. He became very unconfortable at level III questions, so the test was discontinued after question 15. All three subjects were visually handicapped from the age of 6 years old or younger. The performance of subjects who became visually handicapped at or before the age of 6 years seems poorer than that of other subjects: 6 out of 14 early handicapped subjects were responsible for 18 out of 20 incorrect answers/no responses.

Figure 8 gives an overview of the average response times needed for test no.3. They increase with increasing reading level. Average time required to answer a question was 13.5 seconds. The large standard deviations in some cases show, however, that individual response times differ significantly. Average time required to answer all questions per subject was 253.3 seconds. The standard deviation is 13.8 seconds. The fastest subject mainly used vision. He only needed 62 seconds; the slowest one needed 447 seconds for 15 questions only, after that, the test was discontinued (see above). Relatively long times were needed by subjects who fully had to rely on tactual perception, who had poor scanning techniques, who often had to refer to the legend, or those who required relatively long time to answer level III questions. The 5 fastest subjects were good readers, they also obtained a score of 100% correct answers. Given these results, it can be concluded that the questions were answered within 'reasonable' time spans.

DISCUSSION AND CONCLUSIONS

This exploratory study was meant to gain some insights in the possibility to use the multiple static strategy for the representation of temporal changes in maps for people, who are predominantly relying on tactual perception (those with at best 10% residual vision). Because of perception constraints, even with a single map, problems with the accuracy of the answers and response times were expected to increase rapidly with increasing complexity of map reading tasks using multiple maps. In the study, choropleth maps on swell paper were used. Since on this material the expanded image is also appearing in black, the symbols used should preferably both tactually and visually be clearly distinguishable and evoke ordered perception.

Three test were performed on 18 subjects. The purpose of tests no.1 and 2 was to determine whether the symbols developed could be discriminated and ranked. Results show, that the subjects were able to distinguish the patterns clearly. Only one mistake was made in the paired comparison test. Moreover, the patterns allowed spontaneous and unambigious ranking, hence they could be applied to represent ordered data. The aim of test no.3 was to assess whether multiple choropleth maps could be conveniently used to perceive changes in population densities over two decades. Perception was considered to be convenient if at least 75% of the response to each question could be correctly given within reasonable time spans. All questions except one met the criterion of at least 75% correct response. Of all reponses, 94.2% was correct. Only three subjects gave more than one incorrect/no response. Incorrect answers mainly resulted from the fact that one area on the maps was too small. Questions were asked at three reading levels. The expected decrease in accuracy with increasing reading level only occurred from levels II to III, not from levels I to II. At level II, relatively few comparisons had to be made in which the smallest area was involved. Although individual response times varied, all questions could be answered within reasonable time spans.

Comments made by the subjects learn, that the maps were appreciated because of their manageable size, the clear patterns and the contrast. Three of the four low vision subjects liked the combined input through different sensors. The fourth person could not focus on the dots, so he mainly relied on tactual perception. Some subjects found it difficult to find the braille codes in the patterns representing the highest density. Boundaries between adjacent areas with these pattern were also less easy to detect. Perhaps symbol separation needed to be increased. A separation of 2.3 mm is usually enough (Nolan and Morris, 1971[11]), but in practice 3 mm is often applied. Here, separation was less. Another comment was, that it would not be easy to memorize the changes. This could, perhaps, be facilitated by adding some kind of summary graphics (Monmonier, 1992[10]).

The study described here may have some drawbacks. For example, the number of subjects used was relatively small and the concept of reasonable time spans was not precisely defined. Subjects were not required to interpolate data, and memory was not tested. Yet, it is felt that the study shows that investigation should be further pursued to gain more insights. Further studies could concentrate on interpolation or memory. The could also concentrate on different types of maps, on more complex maps with other variables including (perhaps) sound or on dynamic displays through series of vibrations. Some reseach is already going into this direction. The perception of relatively simple multiple choropleth maps seems, however possible.

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New types of city maps using operational scales

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The scale of fixed-scale maps delimits how far the map can be used as a model: its accuracy, adequacy, datelines. A quantitative differentiation of features manifests itself in a map by appropriate methods and graphical variables applied, the elements of contents, being dealt with at the same level of generalization.

A variable scale destroys this order as a whole and introduces quite different type of modeling wherein it is just the scale which depends on accuracy, so on the level of generalization - entirely inversely than in previous case.

The map scale generating can be used:

- to bring out more important elements of the contents (of areas),
- to intensify perception of distribution of individual measurable phenomena in Euclidean metric,
- to vizualize the distribution of complex characteristics, indicators, measurable features in non-Euclidean metrics, and even in semi-metrics.

The most commonly spread are the models developed under assumption of content valorization. The areas (elements) of particular interest for the map user are brought out and, in general, treated more accurately. The perception is facilitated by the methods and visual variables analogous to these used in fixed-scale maps. The map provides better information and increased legibility within the ranges of receiver's interest while no harm is made to visual transfer of general spatial arrangement of important content elements over the whole mapped area. Examples of such types of useful and practical models can be found both in historical cartography (itineraria picta or the Polish plan of Moscow from the 17th cent.) and in contemporary variable-scale plans of cities by Falk [1,4].

In the models of this second type, frequently used in mass-media, the scale is generated as a function of attributes level. For example - the map area between given limits is proportional to the total distribution of football clubs, the population or the electorate - between corresponding limits [2,3,6,8].

In decoding the quantitative information, the direct comparison is of essential importance, e.g. the surface areas of departments being the subject of interest. The role of map background is essentially changed from a partial one of identification nature to an integrated one - which identifies the sub-area and provides the attribute value within the sub-area (the identification is possible since the model maintains the topological attributes of space arrangement, so - among others - the neighbourhood and the closure of sub-areas) [5].

The third type of variable-scale models enables to analyse various phenomena, factors, economically-important characteristics, and even - to get acquaintance of feelings and notions which are related to the quantitative evaluations and which influence to sociological processes or which condition the decisions. Here, characteristics are the cartographical anamorphosis of time availability - simple of a single-pole type, but also complex multi-pole types with lines delimiting the preference areas [5]. While generating the model scale, a consideration is given that the metric matches the type of the variable presented in the map. For instance, in a study of communication availability of road and air route networks in Germany [7], application of appropriate operational semi-metrics has enabled to reveal that Munchen is relatively closer to other state's centres, as concerns the time accessibility, with respect to the accessibility expressed in Euclidean metric of fixed-scale maps.

The paper presents three schemes of operational scale application in thematic modeling of urban areas. Examples are used to illustrate the three before-said types of anamorphosis.

Old Town of Wrocław. Scale 1:1100 - 1:2000. The map is intended for archaeological/preservation services.

This proposal is connected with specific anisotropic large-scale map of Wrocław's Old Town. The changeable scale of map is applied to make possible the most expressively presentation of the main areas with historical buildings. Goals of the map are to facilitate planning the reconstruction of historic town parts in line with modernization of historic buildings and making right decisions about development of tourism.

Three historical parts of Wrocław: Ostrów Tumski (1000), Old Town and New Town (1263) can be distinguished. As there are points in historical part of town (see Fig.1): C - the cathedral, T - the town-hall and B - the post-Bernardine complex, the 1-pole isotropic Falk's rule is not applicable. In this case, it is necessary to use a multi-pole central anisotropic anamorphosis with radial sectors. In practice, the whole of mapped area is divided into six triangular sectors. The sectors have a common apex in the centre of gravity of three middle points of historical part of Wrocław. The main pole is point V - St. Vincent church (1241). Besides of three poles (C,T,B), there were added three new points: A - St.Adalbert's church, U - the University, and M - St.Marys's church. In these seven points the scale of map is 1:1000. The isoline of a 1:1000 scale connects external poles: C B A T U M. Isolines inside the sector are parallel to its direction. The scale is decreasing from the central pole V towards outer poles, reaching the value of 1:2000 in the middle of the distance, then it increases symmetrically. Outside the polygon of satellite poles, the scale decreases in similar way.

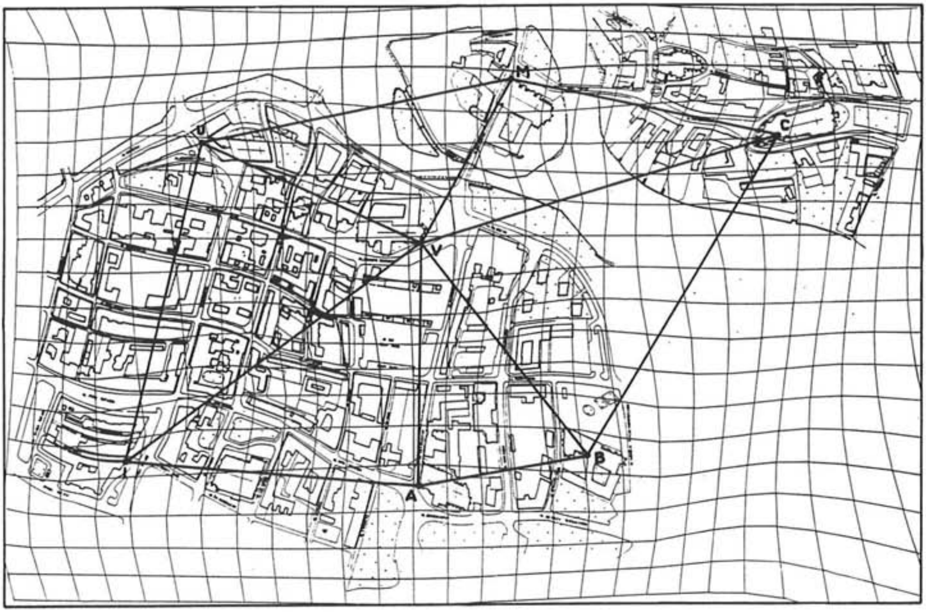

Fig. 1. Anamorphosis of Wrocław's Old Town

Along each of the limits of the sectors VC, VB, ..., VM, the operational scale is changed according to the transformation of the distance $\overline{d} = \overline{d}(d)$.

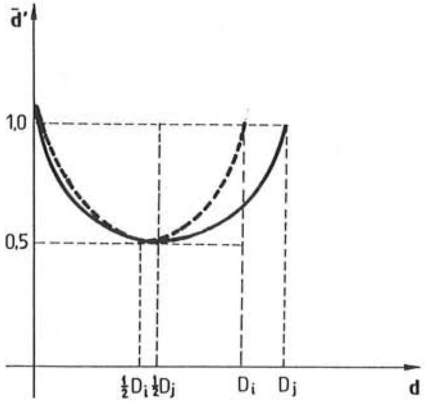

Fig. 2. Graphic representation of the modeling functions $\overline{d} = \overline{d}(d)$.

As:

$$\begin{aligned} &\overline{d}'(0) = 1 \\ &\overline{d}'(D_i/2) = 0.5 \\ &\overline{d}'(D_i) = 1 \end{aligned} \qquad (1)$$

where: $\overline{d}$ - is the distance $\overline{V} - \overline{P}$ along the limit of the sectors (in anamorphosis),
d - the distance V - P (in the map of 1:1000 scale),
D - successive distances: VC,...,VM, (i=1,...,6),

and among many continuous functions $\overline{d} = \overline{d}(d)$ which meet the conditions (1), there is also the parabolic function (see Fig.2):

$$\overline{d}' = \frac{1}{2} + a(d - \frac{1}{2}D)^2 \overline{d}' = \frac{1}{2} + a(d - \frac{1}{2}D)^2 \qquad (2)$$

and while, according to (1), $a = 2D^{-2}$, then:

$$\overline{d}' = 2\frac{d^2}{D^2} - 2\frac{d}{D} + 1 \qquad (3)$$

Thus, finally, the transformation function can be expressed by:

$$\overline{d} = \frac{2}{3D^2}d^3 - \frac{1}{D}d^2 + d \qquad (4)$$

As $D_i \neq D_j$, there are six transformation functions along each limit of the sectors.

A homogeneous picture of the Old Town has been obtained with the most valuable areas of historical buildings brought into relief. The most striking effect of such solutions is the similarity to the rough sea: the highest waves show the most important places, lower - green terrains, the river, habitable buildings (see Fig.1). The orientation of the two main historical routes has been kept: the "amber" (South - North) route along two limits of the sectors AV, VM, and the more recent route (West - East) along the 1:1000 external isoline. The map is made in an automated line: digitizes - computer - plotter on the basis of the map in a 1:500 scale transformed to the scale 1:1000. Despite a considerable reduction of map size, there were no need to reduce its contents, and a good legibility has been maintained.

Map of the Representativeness of Points Network for Measuring Atmospheric Pollution in Wrocław.

The network for measuring the dustfall (dia. less than 5 μm) in Wrocław comprises 93 points. Their representativeness for the purpose of modeling the dustfall distribution is not ensured since the density of network (being discrete) is not adapted to the gradient of the attribute (being continuous) over the area analyzed.

The annual dustfall values (in tons/sq. km), taken from the District Sanitary/Epidemiology Station in Wrocław for 1990, have been divided into 7 classes with the average values $\overline{W}_i$ as follows:

50, 70, 90, 120, 150, 180, (250);

Six classes contain the values which do not exceed the admissible level of 200 tons/sq. km, while the 7th class includes three values: 233, 234 and 282. When classifying, the condition of relative average deviation, $\frac{\sigma_i}{\overline{W}_i} \leq 8$ %, has been satisfied. If this value is decreased (e.g. to the level of 5 % used in Poland, then, when evaluating the cubage of useful minerals indirectly) the number of classes should be increased which would result in lower legibility of the isoline map.

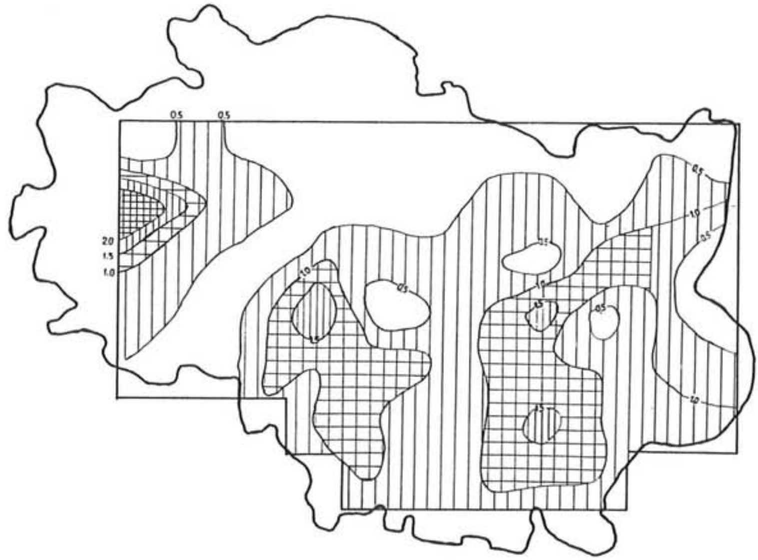

Fig. 3. The Euclidian model of repsentativenes of points network for measuring atmospheric pollution in Wrocław.

In any distinguishable subset P including n_p points wherein the attribute W is measured, seeing that the condition:

$$\frac{1}{30}(\overline{W}_j - \overline{W}_i) = j - i + 1 \tag{5}$$

is met for the classes $i \neq j$, it is possible to define a <u>representativity index</u> $\frac{1}{r}$, while having:

$$\begin{aligned} r &\overset{df}{=} 1 && \text{for } n_p = 1 \\ r &\overset{df}{=} \frac{j-i+1}{n_p} && \text{for } n_p > 1 \end{aligned} \tag{6}$$

For $r \in [2 - 2.5]$ - the representativity is especially low
$r \in [1.5 - 2)$ - the representativity is low
$r \in [1 - 1.5)$ - the representativity is insufficient
$r \in [0.5 - 1)$ - the representativity is correct.

The value of "r" has been calculated for all 68 fields (each of about 4 sq. km area) of the square network inscribed into the borders of Wrocław. These values have been assigned to the central points of the network squares and the isoline model (Fig.3) has been developed. In this way four concentration areas have been revealed around the "critical" points A, B, C, D which indicate the least reliable determinations of the dustfall level in the continuous model.

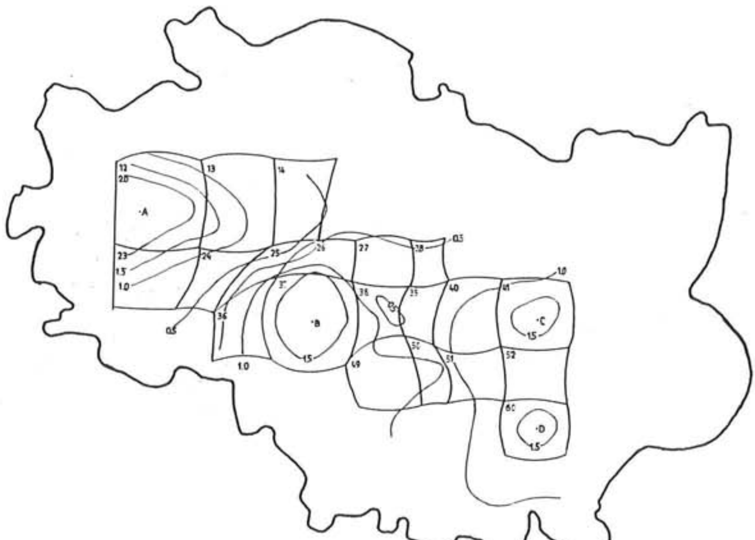

Fig. 4. Anamorphosis of repsentativenes of points network for measuring atmospheric pollution in Wrocław.

Keeping fixed the positions of four poles A, B, C and D - wherein the "r" reaches local maximum levels of 2.5, 2.0, 1.67 and 1.67 respectively - the transformation of the isoline model "r" has been defined as:

$$d_i^* = d_i \bar{r}_i \frac{\sum d_i}{\sum d_i r_i} \tag{7}$$

where: d_i^* - distance between isolines r_i, r_{i+1} in anamorphosis,

d_i - distance between isolines r_i, r_{i+1} in a fixed-scale map,

$\bar{r}_i$ - value of $\frac{1}{2}(r_i + r_{i+1})$,

$\sum d_i$ - D between the poles (in ABC and BCD triangles).

This way, an anamorphous image of the initial square network has been reached (Fig.4) wherein the areas requiring the measuring point network to be more dense are considerably magnified (fields: 12, 13, 23, 37, 41, 49), while the areas in which the measuring points can be reduced (25, 28, 39, 50) are contacted. Revealed are streaks of expansions: 12 - 13 - 14, 41 - 52 - 60, and strips of contractions: 28 - 39 - 50, 25 - 26 - 27 - 28, as well as local anomalies of network density, e.g. a neighbourhood between 25 and 37, 49 and 50 or 28 and 40. The numbering of squares causes easier real-terrain identification of areas wherein the measuring point network modernization is advised with no changes in their total number.

The model has distinct operational application: make the municipal services able to arrive at simple, direct, visual conclusions. A change in square shape and in field sizes improves perception of attribute distribution.

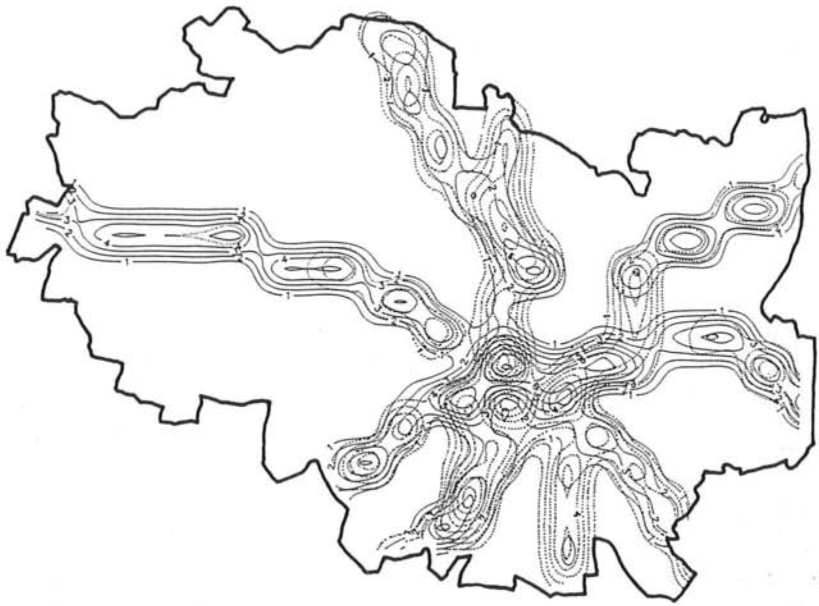

Fig.5. The Euclidean horizontal and vertical road-transition.

Models of Wrocław Road Communication

The superposition of two output isolinear pictures of the road-transition in orthogonally assumed directions has allowed to design a resultant anamorphosis of preference.

Using the map of Wrocław made to the scale of 1:80000, there has been determined, within the squares of 5 x 5 cm, the sums of lengths, in cm, being the projections of national roads onto the vertical axis to get the coefficients of road-transition (disposable) along South - North direction. Spline functions have been used to continualize the discrete values of these coefficients (in centres of squares), (see Fig..5). Analogously, a model has been derived for the traffic preference (disposable) along East - West direction.

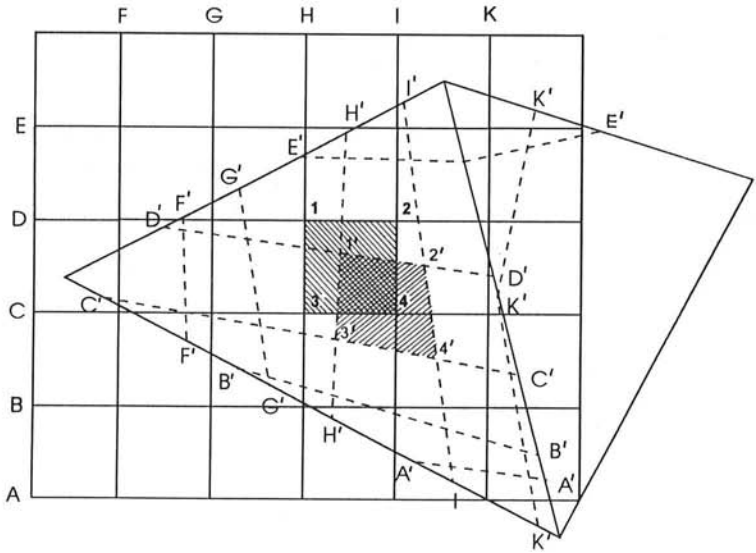

Fig. 6. The design of network of anamorphosis model of tansition.

The anamorphosis is construed by selecting for poles several intersection points of equivalent isolines of vertical and horizontal preferences. The poles, being the isotropic points of road-transition are the vertexes of triangles covering the city area. The sides of the triangles are axes of transformations, according to the rules (7), for the positions of intersections between limits of stripes and columns. The isoline model of coefficient distribution for horizontal road-transition is used to determine the values at intersections between the limits of strips and anamorphosis axes, while the model of vertical road-transition coefficients goves the values at intersections between columns and the axes (see Fig.6).

A simpler cartographical anamorphosis of preference zone road-transition in horizontal and vertical directions can be developed by transforming the positions of strip limit intersections on eastern lines of column limits, and of column limits - on southern limits of strips. The values of zone road-transition coefficients vertical in columns "j" and horizontal in successive strips "i" are specified as follows:

$$\overline{v}_j = \frac{1}{5m_j}\sum_i \Delta v_{ji}$$
$$\overline{h}_i = \frac{1}{5n_i}\sum_j \Delta h_{ij} \tag{8}$$

where: n_i - number of squares in the strip "i",

m_j - number of squares in the column "j",

v - length (in cm) of road projections onto the vertical axis,

h - length (in cm) of road projections onto the horizontal axis.

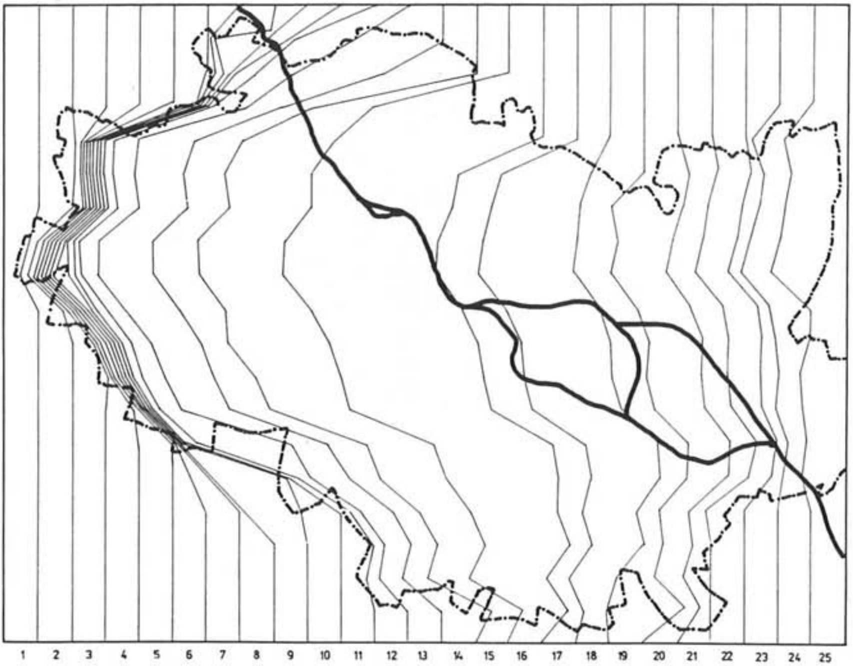

Fig. 7. Operational map of zone road-transition (South -North).

The transformation of the network side "length" is to express the diversification of vertical road-transition . To this purpose, the following series of values is calculated in the column "j" (normalized according to the span within the city borders):

$$\overline{v}^{n}_{ij} = \overline{v}_{ij}\frac{n_i}{\sum_j v_{ij}} \tag{9}$$

and then, the southern limits of strips are treated as successive axes of transformations of positions of vertical column limit intersections (see Fig.7).

A composition of analogous model for horizontal zone road-transition enables to built a general model of road-transition preference. The width of bands is interpreted as a measure of relative road-transition preference: the columns - in vertical, and the strips - in horizontal directions. Due to difficulties in identification, these two families of lines must be visually differentiated. In Wrocław, the cross-over barrier is the Odra River, especially in western part of the city where there are no bridges. It is shown by a value of vertical zone road-transition isoline (Fig.8).

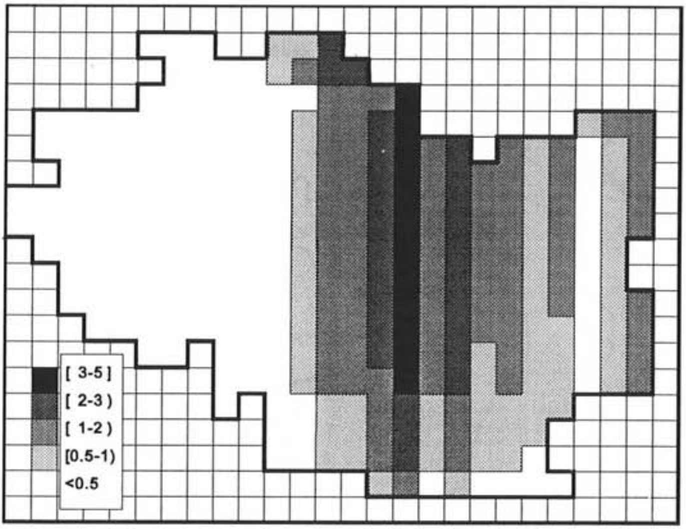

Fig. 8. The Eucldian model of zone road-transition (South-North).

The road availability analysis is facilitated by developing, in a similar way to above models, the road-transition hindrance coefficient. However, due to numerous zero values, some unpassable zones are created when using spline modeling of the road-transition for Wrocław (along national roads), so the anamorphosis gets less legibly. Under such conditions, it is purposeful to compose the anamorphosis as a map of zone "suppression" - the result is then easy to understood and the map can be applied to modernize the arrangement of city roads.

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