CROSS-MEDIA PUBLISHING OVER SCALES

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Abstract

Cartographic Information Systems are still in a development process. They largely deal with functionalities, but often do not concentrate on visualisation aspects. The solutions vary from pure GIS without cartographic characteristics to systems that are simply based on scanned maps, ignoring the technical restrictions of the screen as an output medium.

The interactive Atlas Information System of Austria presents a happy medium: A hybrid system relying on cartographically improved map graphics suitable for both screen visualisation and high-quality printing. By establishing connections between the two media, a method for the production of adequate paper maps as an integral part of the system should be smoothed.

This paper discusses research results at the Vienna University of Technology concerning the topics mentioned above. It will focus on technical restrictions of the screen as an output medium, the adaptation of map graphics and interdependencies between resolution and scale. As an example, the usability of related map graphics for 1:250k screen visualisation and 1:1mio printing will be discussed. As an example the usability of defined 1:250k screen-adapted map graphics for the publication of 1:1mio paper map series will be discussed.

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1 INTRODUCTION

For the last 20 years, the Internet has been the new information transfer medium for cartography and cartographic applications. It offers a variety of ways to communicate spatial information through the adequate visualisation of basic spatial data (topographic and thematic data). Important application areas are regional, national and global atlases in the form of web-based, multimedia and interactive Atlas Information Systems (AIS).

When editing such a map work; it has to be regarded that multimedia as a new expression form is in the middle of a fast developing process. Therefore the rules and grammars of cartographic processes are often broken. Through the visualisation and the embedded functionalities, different user groups may obtain information about the presented area in real time.

The map graphics pose as an essential part of the graphical user interface (GUI) that enables the user to investigate the underlying data. It is important to limit the range of possible interactions to reasonable functionalities. This should be done without making the user feel restricted. Therefore this form of navigation is called "restrictive-flexible" [Gartner et al. 2005].

Using legible map graphics which are adapted to the technical requirements of the output medium is one of the main criteria for user acceptance. Concerning the definition of characteristic sheets for printed maps, much experience has been gained within the last few decades.

The situation is not the same for screen visualisation. Electronic atlases [Elzakker 1993] have not yet reached a high level (especially concerning the legibility of the represented spatial information). Often the implemented maps are merely scanned analogue maps. Due to their technical restrictions, screen presentations suffer from deformation of the graphic elements that limit the legibility of the map. That is why the adaptation of these map graphics is imperative. This could be done by:

- defining minimal dimensions (size and distance) of map graphics and lettering which is dependent on direction and shape,
- thoughtful choice of the basic elements for graphic representations (points, lines, polygons, complex map signs and characters) and
- deliberate choice and combination of graphic variables (size, shape, colour, orientation, lightness and patterns).

This listing is specifically focussed on thematic maps, but is also valid for topographic data. In the following, the authors will concentrate on the representation of topographic data.

The application of screen-adapted map graphics takes up more map space. Thus, it has an effect on the information content of the atlas map. By the implementation of interaction tools, the lower graphic density is compensated by the ability to fully investigate the system.

In addition, the system should provide the possibility to print the resulting purpose- and/or user-oriented maps in high quality. This duality requires cross-media-adapted map graphics for different scales which is the topic of the work presented in this article.

2 CHARACTERISTICS OF ATLASES

The original meaning of the term “Atlas” refers to Greek mythology. Atlas was one of the Titans, a group of gods who fought an unsuccessful war against Zeus and the other Olympian Gods. Zeus punished Atlas by forcing him to carry the sky on his shoulders forever.

“Atlas” was first used as the name of a collection of various maps by Gerhard Kremer (1512-1592, better known as Mercator). He used this term for the “Atlas sive Cosmographicae Mediationes de Fabrica Mundi et Fabricati Figura” – a collection of 74 maps first published in 1585.

Figure 1. Front page title and a map of the "Atlas sive Cosmographicae Meditationes de Fabrica Mundi et Fabricati Figura" [URL1].

2.1 A Definition

According to the encyclopaedia of Cartography and Geomatics [Bollmann et al. 2002], an atlas is a functional and systematic collection of maps in the form of books, loose sheets or files for the electronic representation on the screen (AIS). An atlas with its local, regional or global character offers not only maps, but also statistic information like texts, tables, figures and pictures as well as computer-aided dynamic elements like voice, sound, animation and video clips.

The structuring of this information is based on the given objectives [Kraak et al. 1996]. The primary target is to visualise global or local regions and to point out dependencies on a wide spectrum of additional thematic information. It is particularly important to transmit the patterns of our physical, temporal and socio-economic environment.

Kraak [2001] stated that atlases can be considered as the ultimate cartographic product because they are most widely known and used. Presumingly this wide acceptance of cartographic products is induced in early education, where children first get in touch with maps and atlases.

2.2 From Traditional Paper Atlases to Atlas Information Systems (AIS)

Traditional paper atlases have a fixed linear structure – fixed by means of the format and (depending on the representation area) the limited scale range and linear according to the sequence of themes. Maps have a dual purpose: on the one hand they have to store spatial information and on the other hand they try to communicate it. Often there are additional elements like statistics, diagrams and other forms of static information transmitters which are mentioned above.

In table 1 Ormeling [1996] summarised a comprehensive list of characteristics of paper and web atlases. He considered view-only atlases and paper atlases as the same category. According to his arguments, view-only atlases do not use technology "adequately". He explains that although view-only atlases are digital atlases they do not take advantage of the resources available in the digital medium. He made use of multimedia and dual concepts (static vs. dynamic, passive vs. interactive) to analyse the differences between paper and digital maps.

By taking a closer look at the table, it is possible to come to the conclusion that the only advantage of paper maps is their resolution.

Table 1. Differences between static and interactive / analytic atlases (after Ormeling [1996]).

Paper atlas/View-only atlas	Interactive atlas/Analytical atlas
Static	Dynamic
Passive	Interactive
Maps only	Maps and multimedia
Limited selective	Complete
Fixed map frames	Panning and zooming possible
Compromise for all type of use	Customised
Maps as final product	Maps as interface

Digital technologies attempt to free cartography from these limitations. The emergence of digital technologies enforced the omnipresence of interactive maps. It is to be expected, that the barriers of static cartography will be negotiated by the standardised implementation of AISs in the near future [Ormeling 1996, Asche 2001], which could enable an easier access to geographical data.

The birth of digital atlases (AIS) was characterised by hardware limitations (storage capacity) as well as the lack of appropriate software (authoring tools for the development of interactive applications). The first developed digital atlas was the "Electronic Atlas of Canada" from 1981 [Siekierska et al. 1996]. Since then, increasing research efforts have been carried out [ICA 2005] not only by universities, but also governmental organisations and private companies.

In modern cartography of the late twentieth century [Robinson et al. 1995], the internet offered an ideal platform for communication via maps. The new web technology and lower equipment costs allow everyone, even those without cartographic knowledge, to visualise spatial information by producing their own cartographic products. For modern cartographers it has become even more important to enforce their competences in:

- the realisation of new presentation forms for the visualisation of spatial information in interactive, analytic and/or multimedia form as well as
- a deep concentration on the whole cartographic communication process (from data acquisition to adequate data representation).

Regarding these new presentation forms [Ramos et al. 2005], it is noticeable that the paper map is usually not the final product any more, but often acts as a user interface where dynamic exploration of the underlying primary data takes place through interactive system functionalities. Depending on their experience and objectives the users themselves define their individual form of geo communication [Lechthaler 2004b]. Therefore it is essential to use optimally prepared map graphics. To support interactive data exploration through database queries and resulting visualisations, the map elements have to be linked to their corresponding original objects [Lechthaler 2004a, Persson et al. 2005, Stadler 2004].

More than ever before there is a great need to apply rigorous cartographic principles, good design techniques and skills, with the aim of making the communication of spatial information from AIS richer, more efficient and possibly even more personalised.

Via an access to primary data, the deficiency of data transmission caused by the technical restrictions of the screen is compensated. By a matter of fact, the systems do not suffer from limitations concerning the data exploitation any more.

2.3 The Map as User Interface in an AIS

According to Goodchild [2000], cartography is an essential element for the future of geography and therefore also for the future of geographic information sciences. The introduction of digital maps and their daily use leads to a constantly growing demand on efficient cartographic products as a basis for visual communication of cartographic and geographic information systems (KIS, GIS). Especially in an AIS (as a special implementation of KIS) the map is the most important element. It serves as an interactive and dynamic multimedia information medium and thus is a guiding tool, that helps the user to explore the system either on a predefined or on a self defined path and leads to a deeper knowledge about spatial phenomenons and processes. In this context Ormeling [2001] uses the metaphor of a “geographical switchboard”.

Problems of insufficient information transfer due to larger map graphics which are caused by screen adaptivity, can be overcome by accessing primary data and can thus lead to a more efficient system with hardly any capacity limits.

3 SCREEN-ADAPTED CARTOGRAPHIC VISUALISATION

The design of screen-adapted atlas maps is a big challenge for cartographers. During the design process and editorial work they have to be both: “map makers” and “system designers”. Their tasks include scale-dependent adaptation of generalisation and visualisation as well as the preparation for an optimal use of the screen as an output medium and the Internet as a transport medium.

As long as the screen is only part of the production process of an analogue map, the low resolution is no obstacle. For the visualisation on screen, the map is the central object and therefore the attention has to be turned towards the design of the map graphics.

Good map graphics should [Keates 1989, Spiess et al. 2002, Hake et al. 2002]:

- mediate spatial information,
- ease the map face by highlighting substantial contents,
- ensure the required accuracy in position,
- use associative signs,
- convey a clear and correct message,
- follow cartographic guidelines and

- be legible.

The visualisation of digital maps according to the characteristic sheet results in deformations of the map face caused by the technical restrictions of the screen. Thus the characteristic sheet has to be adapted to the requirements of the new output medium. In this respect minimal dimensions play a crucial role. Their definition is highly connected with the resolution achieved on the screen.

3.1 Technical Restrictions of the Screen as an Output Medium

When producing a digital map, the device-independent pixels (of which graphics are internally composed) have to be converted into those output pixels one can see on the screen. The number of output pixels defines the resolution of the screen. It is the most important restriction of this output medium. Other restrictions are the form of output pixels, the colour depth, image interferences and the refresh rate.

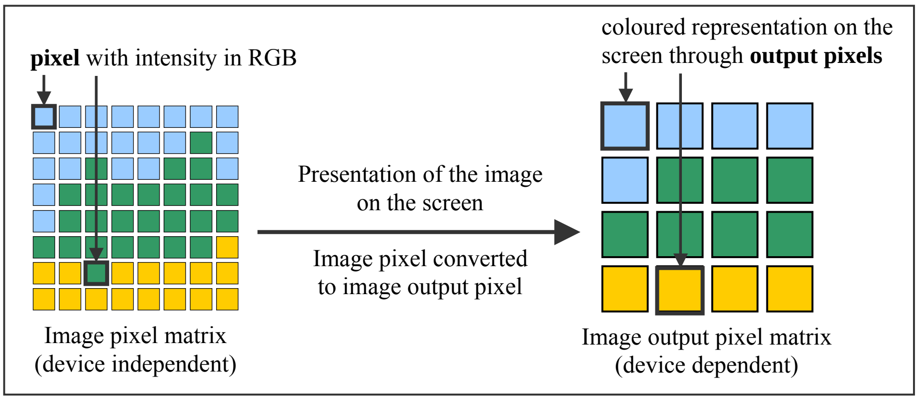

Figure 2. From device-independent pixels to device-dependent output pixels.

3.1.1 Pixel, Output Pixel, Size and Resolution of the Output Medium

A pixel is the elementary element of a digital pixel matrix. Each pixel stores an individual intensity value, which will become visible when visualised on the intended device, which could be a screen or a printer. Therefore the pixels have to be converted to a different amount of pixels (see figure 2) with different sizes, which depends on the resolution of the used device:

Size of pixel = size of output medium / resolution of output medium

The average pixel size lies between 0,2mm x 0,2mm and 0,4mm x 0,4mm and the average printing resolution is about 0,1mm. According to this the screen resolution is about 2-4 times lower than the resolution of the printed map.

For the following investigations the authors defined an average size of pixels which then served as a conversion factor between the amount of pixels and the covered screen size. In order not to neglect screens with a lower resolution, values within the interval were given a higher value than usual: 1 pt (typographic point[1]) = 0,375 mm [Bollmann et al. 2002].

3.2 The Basic Rules of Screen-Adapted Visualisation

As described above, the technical restrictions of the screen result in image interferences, which should be reduced by the implementation of screen-adapted map graphics. Thus an attractive map appearance is created, which is the precondition of a good graphical quality map and a high user acceptance. In order to achieve an attractive map design, it is crucial that:

- map graphics are legible and the graphic density is not too high,

[1] „Typographic points“ are used in letterpress to define the size of fonts.

- the resolution of the map is adapted to the resolution of the presenting screen,
- the signs are differentiable,
- the colours are assembled harmoniously and
- the overall layout is visually pleasing.

In order to fulfil these criteria, it is necessary to invent minimal dimensions for representations on the screen. Beyond that, recommendations for the right choice of colours and lettering as well as shapes, patterns and orientation should be given.

3.2.1 Minimum dimensions

When changing the scale of a map to a smaller scale, the representation of objects diminishes until it is not legible any more. Therefore the size of the objects which are yet legible is of great interest [Stadler 2004].

Minimum dimensions are minimum values for the perception (or legibility) of graphic elements (respectively map elements) concerning their size and distance from each other under normal conditions of perception [Bollmann et al. 2002].

They depend on two factors:

- the aligning power (resolution) of the human eye and
- the restrictions of the used output medium and/or the efficiency of the used map production techniques.

The aligning power is the distance at which two points can still be perceived separately. It depends on the reading distance, on the wavelength of the surrounding light and on the visual faculty of the user. In case of normal daylight, the following values for the aligning power can be identified [Neudeck 2001]:

Table 2. The aligning power of the human eye depending on the reading distance (Neudeck [2001]).

Reading distance	Aligning power
30 cm (paper)	0.05 mm
60 cm (screen)	0.10 mm[2]

Concerning the definition of minimum dimensions, it is important to remain above these values. The technical limitations for printing cause a minimum line width of 0.1 mm. Presuming an average reading distance of 30 cm, the value is twice as high as the aligning power for this distance and therefore suitable as a minimum dimension. This and other important values are listed in table 2. Due to the coarse resolution, the minimum dimensions for screen representations clearly have to be higher.

Table 3. Minimum dimensions for paper and screen (Malić [1998], Neudeck [2001]).

	Minimum dimensions for paper		Minimum dimensions for screen		
Line widht	0.1 mm		1 pt	0.4 mm	
Line distance	0.2 mm		2 pt	0.8 mm	
filled square	0.3 mm		3 pt	1.1 mm	
filled disc	0.4 mm		4 pt	1.5 mm	
filled rectangle	0.3 mm x 0.6 mm		3 pt x 6 pt	1.1 mm x 2.3 mm	
horizontal font	5 pt = 1.9 mm	writing	10 pt	3.8 mm	Verdana
curved font	7 pt = 2.6 mm	writing	14 pt	5.3 mm	Verdana

The values listed in Tab. 3 refer to the inspection of strongly contrasted map elements under normal light conditions.

[2] The aligning power of 0,10 mm from a distance of 60 cm is an obvious indicator for singular pixels (with the size of 0,20 mm x 0,20 mm to 0,40 mm x 0,40 mm) to be easily perceived.

3.2.2 Screen-adapted visualisation

Besides regarding the minimum dimensions, it is fundamental to consider some other restrictions concerning the map design. In terms of colours, there are hardly any technical restrictions. Depending on the colour depth, a variety of colours (defined by their additive RGB-values) may be generated. To achieve standardised representations, indexed web colours have been developed. Their intensity differences fulfil the requirements of colour differentiation. Furthermore, the traditional demands on the use of associative colours and the clear distinction between foreground and background colours have to be met.

In terms of shapes, directions and patterns, the following conditions should be kept:

- the use of rectangles and squares instead of circles, triangles or complex signs,
- alignment parallel to pixels (prevention of transverse lines or signs),
- avoidance of different line styles (dashed lines, double lines) and
- scarce use of linear elements (no area borders).

4 SUGGESTIONS FOR SCREEN-ADAPTED MAP GRAPHICS WITHIN AN AIS

When thinking about a definition for map graphics, the dual character of the system has to be regarded. The system should provide visualisations suitable for the screen as well as high-quality printouts. We have learned that these two output media differ in terms of technical and formal restrictions. To stay legible, adapted map graphics have to be used in both cases.

Because automated generalisation is not possible yet, maps can not be derived on-the-fly in individual scales. Therefore it is necessary to define a series of fixed scales that can then be cartographically processed. Each of those scales represents the real world in another spatial resolution. The interactive data exploration tools represent the only link between the map graphic and the original data (primary data).

For that reason it is advisable to define an individual succession of scales for each output medium and to create cartographically prefabricated and, in regard to the content, harmonised scale levels by adapting the map graphics which represent the real world in different spatial resolutions. Deformations of the map graphic by screen interference should be kept to a minimum, which is why only limited zoom areas within a scale level should be allowed.

4.1 Screen-adapted characteristic sheet for the basic map

Because of the individual parameters of different screens, a definition of minimum dimensions for screen-adapted characteristic sheets is very complex. Table 4 shows minimum dimensions for lines, for distances between two lines, for basic shapes and for fonts. Moreover limitations according to the selection of colour, shape and font styles are substantial.

In consideration of the basic rules of screen-adapted visualisation, the authors developed a recommendation for the characteristic sheet of the basic map, which is the largest scale level of an AIS (see figure 3). This should guarantee a high-quality presentation of the topographic objects on screen in the desired scale.

Table 4. Recommended characteristic sheet of the basic map (scale 1:250k).

Content layer (hierarchical succession)	Style, Dimensions (1 pt = 0.375 mm)	RGB-colours (Hexadecimal- / Decimal-code)
Town symbols:		
less than 10’000	Square 5 pt – 1.9 mm	#000000 – 0, 0, 0
10’000 to 50’000	Square 9 pt – 3.4 mm	#000000 – 0, 0, 0
50’000 to 150’000	Square 14 pt – 5.3 mm	#000000 – 0, 0, 0
150’000 to 1’000’000	Square 20 pt – 7.5 mm	#000000 – 0, 0, 0
more than 1’000’000	Square 27 pt – 10.1 mm	#000000 – 0, 0, 0
Town lettering:		
general	Verdana, 10 pt, bold	**#000000 – 0, 0, 0**
Provincial Capitals	Verdana, 12 pt, bold, underlined	**#000000 – 0, 0, 0**

Federal Capitals	Verdana, 12 pt, bold, underlined, capital letters	**#000000 – 0, 0, 0**
Roads:		
Motorways	Centerline: 4.5 pt – 1.7 mm Width: 9 pt – 3.4 mm	**#FFFF00 – 255, 255, 0** **#FF3333 – 255, 51, 51**
Main Roads	4 pt – 1.5 mm	**#009900 – 0, 153, 0**
Freeways	2 pt – 0.8 mm	**#FF3333 – 255, 51, 51**
Rail:	Dashed: 4 pt – 1.5 mm	**#000000 – 0, 0, 0**
Waterbodies:		
Rivers:	1.5-4 pt – 0.6-1.5 mm	#3366FF – 51, 102, 255
Lakes:	Filled area (without border line)	#6699FF – 102, 153, 255
Borders:		
States	Centerline: 2 pt – 0.8 mm Width: 14 pt – 5.3 mm	**#666666 – 102, 102, 102** **#CCCCCC – 204, 204, 204**
Provinces	Centerline: 2 pt – 0.8 mm Width: 9 pt – 3.4 mm	**#666666 – 102, 102, 102** **#CCCCCC – 204, 204, 204**
Districts	Centerline: 2 pt – 0.8 mm Width: 5 pt – 1.9 mm	**#666666 – 102, 102, 102** **#CCCCCC – 204, 204, 204**
Municipalities	2 pt – 0.8 mm	**#CCCCCC – 204, 204, 204**
Permanent settlement area:	filled area (without border lines)	#FFCC99 – 255, 204, 153
Austria:		
state area	filled area	#FFFFCC – 255, 255, 204
ToolTips:		
Smallest Administrative Areas	Verdana, 10 pt, fett	**#000000 – 0, 0, 0**
Waterbodies (Rivers, Lakes)	Verdana, 10 pt, fett	**#3366FF – 51, 102, 255**
Neighbouring Countries	Verdana, 10 pt, fett, capital letters	**#000000 – 0, 0, 0**

The specifications concerning style, dimension and colour can be viewed in table 4. The displayed succession of the content layers corresponds to the hierarchy in the map, meaning that an element at the top of the table cannot be covered by an element mentioned further down in the table.

The dimensions are specified as pixels and as metric units. The typographical point serves as the conversion factor. The choice of colour is based on the palette of indicated web colours (hexadecimal and decimal code).

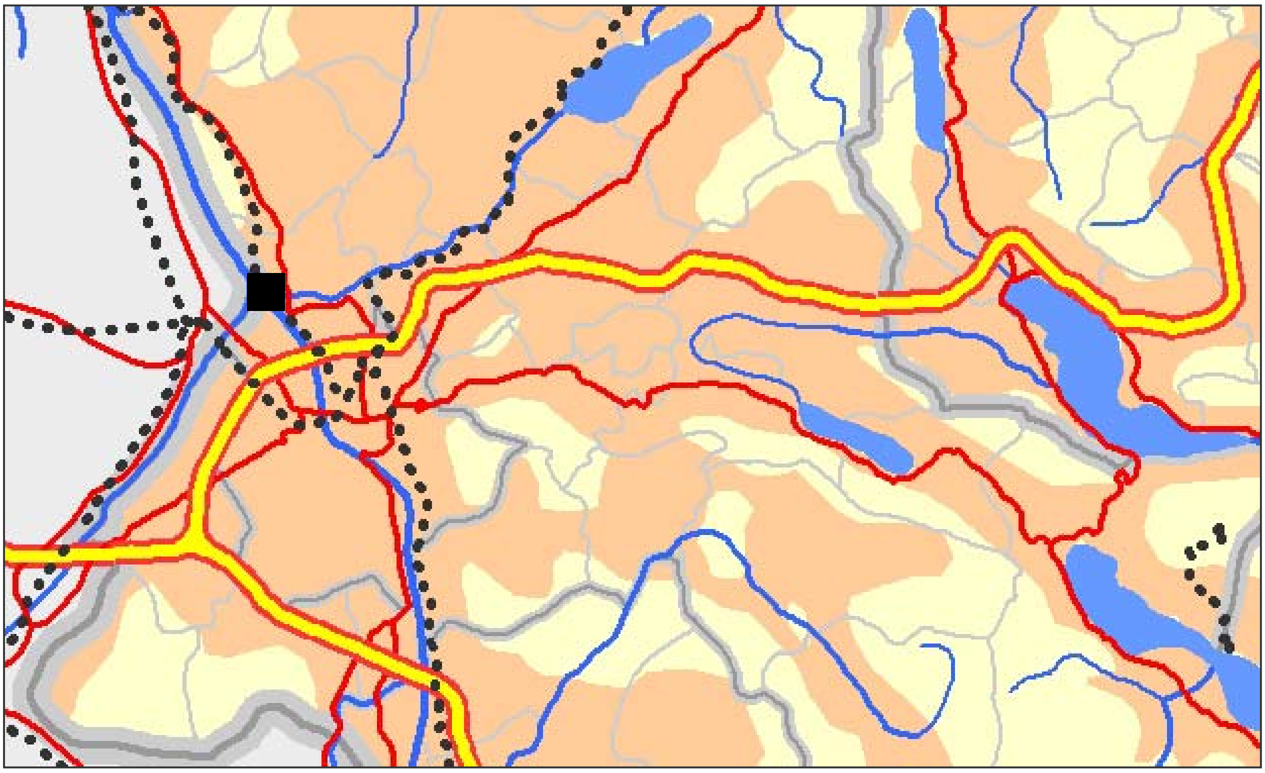

Figure 4. Extract of a screen-adapted map in scale 1:250k (100dpi).

4.2 Screen-adapted characteristic sheets for printed maps in high-quality

When designing a map for the presentation on screen, significantly higher minimum dimensions than for printed maps have to be considered because of the lower screen resolution. Presuming a relatively large pixel size of 0,375 mm (1 pt) and an average printing resolution of 0,1 mm, the resolution of the medium screen is about 4 times lower. This implies, that a screen-adapted mapwith a scale 4 times larger, but yet with the same density of information as the coresponding printed map, is acquired.

Figure 5. Extract of a ready-for-printing map (1:1 Mio, 400 dpi).

Since there are no reasons, why a screen-adapted map could not be used for printing, it was decided to print this map in a scale 4 times smaller than the original map.

5 CONCLUSIONS

Maps which are adapted to screens and serve as a graphical user interface in an interactive AtlasInformationSystem (AIS) are the new generation of maps. Primary data (geographical basic data in the form of geometry and statistics) can be accessed via interactive system functionalities of map graphics which need to be clear, precise, legible, adapted to the used scale and adapted to the technical requirements of the output device screen.

Beside the presentation on screen, the modern user also expects an analogue output. This paper presents a method to generate map graphics of an AIS with a special emphasis on cross-media and the principles of scale-adapted cartographic data preparation.

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