Output Media Adapted Cartographic Visualisation

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Abstract

In modern cartography of the late twentieth century, the Internet offers an ideal platform for the communication via maps. The map graphics pose as an essential part of the graphical user interface in Atlas Information Systems (AIS) that enables the user to investigate the underlying data.

Existing AIS largely deal with functionalities, but often do not concentrate on visualisation aspects. The solutions vary from simple line graphics with hardly any cartographic characteristics to systems that are based on scanned maps, ignoring the technical restrictions of the screen as an output medium. So the authors are searching for high-class AIS which should rely on cartographically improved map graphics suitable for both, screen visualisation and high-quality printing.

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. Due to their technical restrictions, screen presentations suffer from deformations of the graphic elements. In order to produce legible maps, the map graphics have to be adapted to the screen.

Keywords--- **interactive atlas information systems (AIS), cartographic visualisation, map graphics, graphical resolution of output media.**

1. Introduction

According to Goodchild [4], cartography is an essential element for the future of geography and geographic information sciences. The introduction of digital maps and their daily use lead to a constantly growing demand on efficient cartographic products.

For the last twenty years, the Internet has been the new information transfer medium for cartographic applications. It offers a variety of ways to communicate spatial information through the adequate visualisation of basic spatial data (topographic as well as thematic data). It is no big surprise, that the most important application areas are regional, national and global atlases in the form of web-based, multimedia and interactive AIS.

Especially in case of an AIS, the map is the most important element. It serves as an interactive and dynamic information medium and thus is a guiding tool that helps the user to explore the system in order to get a deeper knowledge on spatial phenomena and processes. Ormeling [16] uses the metaphor of a “geographical switchboard”.

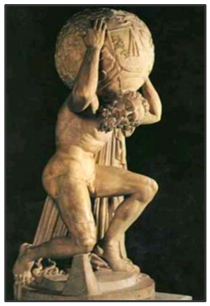
Through the visualisation and the embedded functionalities in AIS, different users may obtain individual information about the presented area in real time. To support interactive data exploration through database queries and resulting visualisations, the map elements have to be linked to their corresponding original objects [17, 21]. Via an access to these objects, the deficiency of data transmission caused by the technical restrictions of the screen is compensated. As a matter of fact, AIS do not suffer from limitations concerning the data exploitation any more.

But it is important to limit the range of possible interactions to reasonable functionalities. It should be done without making the user feel restricted. This form of navigation is called "restrictive-flexible" [3]. Depending on their experience and objectives the users themselves define their individual form of geo communication [10]. Therefore it is essential to use optimally prepared map graphics by applying rigorous cartographic principles and good design techniques.

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 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.

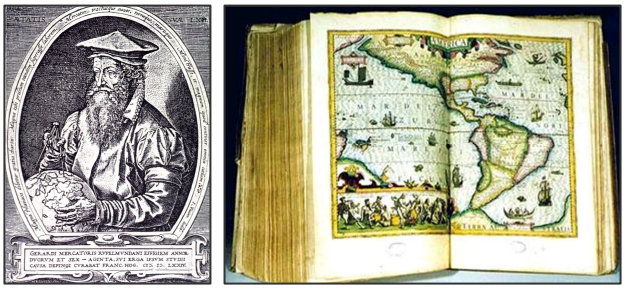
2. Atlas cartography



The original meaning of the term "Atlas" refers to Greek mythology. Atlas was one of the Titans, a group of gods who fought against Zeus and the other Olympian Gods. They lost and Zeus punished Atlas by forcing him to carry the sky on his shoulders forever (figure 1).

Figure 1 God Atlas carrying the sky on his shoulders [23].

For a collection of various maps, the word "Atlas" was first used by Gerhard Kremer (1512-1592, figure 2), better known as Mercator. He used this term for the "Atlas sive Cosmographicae Mediationes de Fabrica Mundi et Fabricati Figura" (figure 3) – a collection of 74 maps first published in 1585.



Figures 2 & 3 Gerhard Kremer (Mercator) and his "Atlas sive Cosmographicae Meditationes de Fabrica Mundi et Fabricati Figura" [24, 25].

2.1. Some definitions

According to the encyclopaedia of Cartography and Geomatics [2], an atlas is a functional and systematic collection of maps in the form of books, loose sheets or files for electronic representation on the screen (AIS). An atlas with its local, regional or global character offers not only maps, but also static 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 given objectives [8]. 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.

Atlases are considered to be the ultimate cartographic products because they are most widely known and used [9]. Presumably 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 as well as the limited scale range (depending on the representation area) and linear according to the sequence of themes.

In table 1 Ormeling [15] summarised characteristics of paper and web atlases. He considered view-only atlases and paper atlases as the same category. According to him, view-only atlases do not use technology "adequately" by disregarding the advantages available resources in the digital medium. He used multimedia and dual concepts (static vs. dynamic, passive vs. interactive) to analyse the differences between paper and digital maps.

paper / view-only atlas	interactive / 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

Table 1 Differences between static and interactive / analytic atlases (after Ormeling [15]).

By taking a closer look at table 1, one could arrive at the conclusion that the only advantage of paper maps is their resolution. Digital technologies attempt to free cartography from these limitations. The emergence of digital technologies enforced the omnipresence of interactive maps. It is assumed that the barriers of static cartography will be abolished in the near future by the implementation of various AIS [15, 1].

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 "Electronic Atlas of Canada" (1981) [20] was the first atlas to be developed. Since then, increasing research efforts have been carried out [6] not only by universities, but also by governmental organisations and private companies.

2.3. Problems caused by new technology

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 take advantage of their competences in:

- the use of new presentation forms for the visualisation of spatial information as well as
- a deeper insight into the whole cartographic communication process (from data acquisition to adequate data representation).

Unfortunately, existing AIS do not necessarily reflect these competences. They largely deal with functionalities, but often do not concentrate on visualisation aspects. The design of maps varies from simple line graphics with hardly any cartographic characteristics (figure 4) to systems that are based on scanned maps, ignoring the technical restrictions of the screen as an output medium (figure 5).

Figures 4 & 5 Examples of digital maps that do not fulfil the requirements of screen representation [26, 27].

So, what the authors are searching for is a hybrid system relying on cartographically improved map graphics. It should be suitable for both, screen visualisation and high-quality printing.

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 visualisation, generalisation and harmonisation as well as the 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. But when it comes to representations on screen, the attention has to be turned towards the design of the map graphics because the map forms the main element of the system.

Efficient map graphics have to [7, 19, 5]:

- mediate spatial information,
- highlight substantial contents,
- ensure topological correctness,
- use associative signs,
- convey a clear and correct message,
- follow cartographic guidelines and
- (most important) be legible.

The visualisation of digital maps using characteristic sheets for printed maps results in deformations of the map graphics caused by the technical restrictions of the screen. Thus the characteristic sheets have to be adapted to the requirements of the new output medium [11].

3.1. Technical restrictions of the screen as an output medium

A pixel is the elementary part of a digital pixel matrix. Each pixel stores an individual intensity value, which will become visible when visualised on the screen.

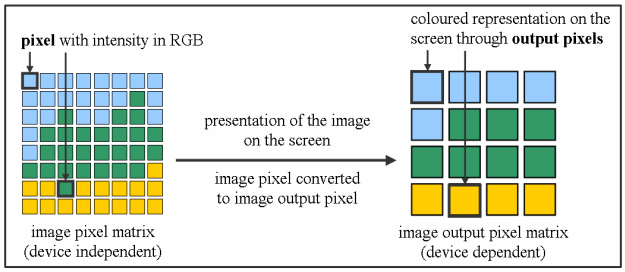


Figure 6 From device-independent pixels to device-dependent output pixels.

When producing a digital map, device-independent pixels (of which graphics are internally composed) have to be converted into those output pixels one can see on the screen (figure 6). This is done by screen masks and ionisation respectively. The size of screen and output pixels then define the resolution of the screen:

Resolution of the screen =
screen size / size of the output pixels

The average output pixel size is between 0.2mm x 0.2mm and 0.4mm x 0.4mm. For the following investigations the authors had to define an average output pixel size which then served as a conversion factor between the amount of output pixels and the covered screen area. In order not to neglect screens with a lower resolution, the constant value of 1 pt (typographic point[1]) = 0.375 mm [2] was chosen.

Compared to the average printing resolution of 0.1 mm, it can be seen that the resolution of the screen is about 4 times lower than the resolution of the printed map.

The low resolution is the most important restriction of this output medium. Other restrictions are the form of output pixels, colour depth, image interferences and refresh rate.

3.2. Minimum dimensions

Depending on the resolution of the output medium, we have defined minimum dimensions. They 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 [2].

Since the resolution of the screen was defined to be app. 4 times lower than the resolution of printed maps, minimal dimensions have to be 4 times larger.

The minimal line width for example is 0.1 mm in paper maps. This equals the printing resolution.

[1] The „typographic point“ is used in letterpress to define the size of fonts.

Assuming a minimal line width of screen representations which should equal the screen resolution, it would be 1 pt or rather 0.4 mm (table 2).

The only distinctions have to be drawn when it comes to lettering. To be legible in printed maps, it has to be relatively larger. To find reasons for that will be part of our future studies.

	min. dim. for paper		min. dimensions for screen		
line width	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 circle	0.4 mm	.	4 pt	1.5 mm	●
filled rectangle	0.3 x 0.6 mm	.	3 x 6 pt	1.1 x 2.3 mm	▬
horizontal font	5 pt = 1.9 mm	text	10 pt	3.8 mm	text
curved font	7 pt = 2.6 mm	text	14 pt	5.3 mm	text

Table 2 Minimum dimensions for paper and screen (Malić [13], Neudeck [14]).

The values listed in table 2 refer to the examination of strongly contrasted map elements under normal conditions of perception.

3.3. Some more basic rules for screen-adapted map design

Besides regarding the minimum dimensions, it is fundamental to consider some other restrictions concerning the map design.

In terms of shapes, directions and patterns, the following rules should be observed:

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

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.

4. Suggestions for screen-adapted map graphics within an AIS

During the cartographic communication process (figure 7) original data is collected and stored in databases but very seldom directly implemented into the map (an exceptional case would be the representation of aerial or satellite images). Normally the so-called basic data only provides a geometrical and thematic basis for the visualisation of map graphics. To be visualised adequately it has to be adapted to the intended scale and output medium by means of symbolisation, generalisation and harmonisation.

Because fully automated adaptation is not possible yet [22, 18], 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 only link between scale-dependent map graphics and original data are interactive data exploration tools. They enable the user to investigate the system and its underlying basic data and thus build up a connection between the 2nd and the 1st model.

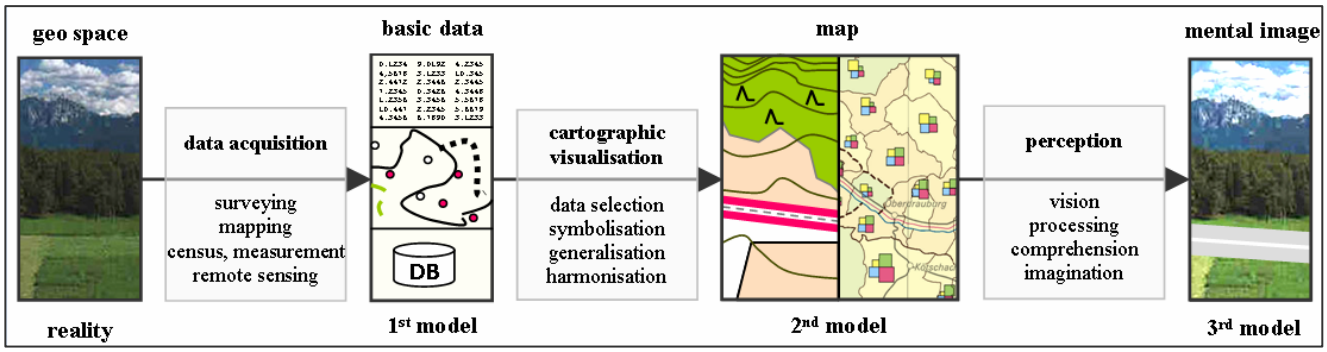


Figure 7 The relevance of modelling for the cartographic communication process.

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, the map graphics have to be adapted for both cases.

For that reason individual successions of scales for both output media have been defined and cartographically processed. In consideration of their purpose, for each scale level the relevant data was selected and adapted.

4.1. Screen-adapted map graphics for the screen

In consideration of the basic rules of screen-adapted visualisation, the authors developed a recommendation for a characteristic sheet of the basic map in scale 1:250k [12]. There screen-adapted signs for several topographic layers (namely political borders, rivers, lakes, streets, railways, big cities and a permanent settlement area) have been defined. In figure 8 the symbolised, generalised and harmonised map graphics are represented.

Using the same signs, further scales may be derived only by adapting the map graphics to the aspired scale.

4.2. Screen-adapted map graphics for high-quality printouts

Besides the presentation on screen, modern users also expect an analogue output. As mentioned before, the resolution of the screen is approximately 4 times lower than that of printed maps. This implies that a screen-adapted map can be used for printing in a scale that is 4 times smaller but has the same information content. So the 1:250k screen map was used to generate a 1:1mio print map (figure 8). As mentioned before, only writings had to be treated separately.

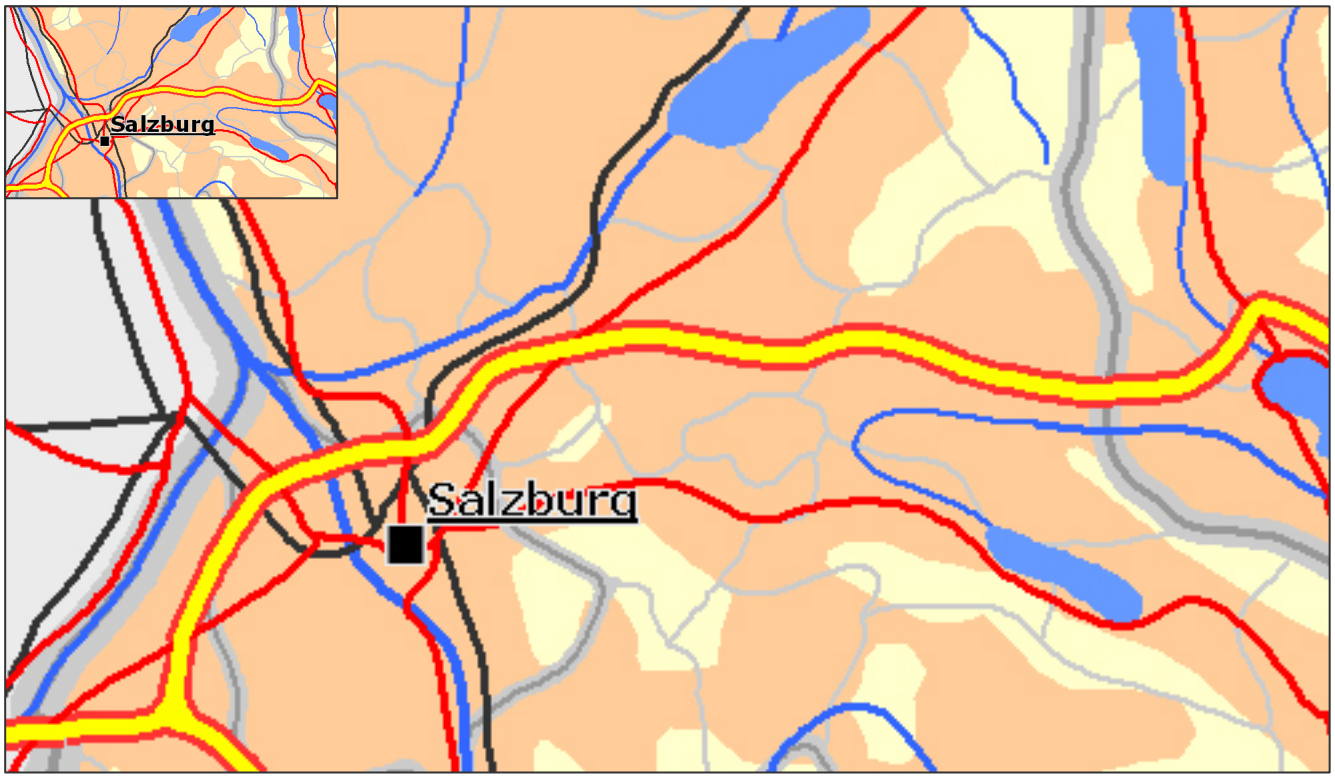


Figure 8 Extract of the adapted screen map (1:250k, 72dpi – standard screen resolution) and the corresponding printout in 4 times higher resolution and therefore 4 times smaller scale (1:1mio, 300dpi – standard print resolution).

Conclusion

The quintessence of this work was to establish connections between screen and paper as different types of output media for cartographic applications in the form of AIS: The resolution of a screen is approximately 4 times lower than the resolution of printed maps, so the minimum dimensions had to be defined 4 times larger. This is why the application of screen adapted map graphics takes up more map space which 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 and all the primary data behind it. Taking into account these principles, both output media may provide satisfying information on the geo space in its entirety.

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