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Hybrid considerations on the sustainability of cartographic heritage

Keywords: Cartographic heritage; reproduction; quality issues; hybrid processes; sustainability.

Summary

The unmistakable importance of cartographic heritage mainly seems to base upon the special treatment of spatial related information within maps. Due to a more effective understanding of the map content spatial data have and had to be simplified and thus interpreted, which generally is and was influenced by political, economical or religious conditions. Thus a deeper insight into a specific time, political system or economic condition with the help of map semiotics and projection may be provided for a historical point of view. Some striking examples may be found in the book "How to lie with maps" by Mark Monmonier. Additionally, maps may be the only available documents in order to explore and prove past situations of real world objects, e.g a natural riverbed before its modification, which is an important issue in actual and future planning processes. It becomes obvious that maps are indispensable documents for attesting various kinds of spatial related situations. When thinking of sustainability of cartographic heritage two main important questions have to be seen: The first one asks for the best and high quality processes to save as well as make accessible historical maps/documents also in a far future. These aspects generally will try to reproduce and copy the original document in order to disseminate some material for ongoing working processes. The second important question focuses on solutions to save and keep accessibility to cartographic products/states of today, including multimedia and Internet applications. This contribution focuses on the first question of cartographic heritage sustainability and should present some considerations on actual and alternate reproduction methods of historical maps. By using the essence of the small project HYREP (hybrid reproduction) - where actual available reproduction methods / techniques were identified, their applicability for damageable documents/maps considered, alternate possibilities of hybrid reproduction developed and a rough comparison of reproduced qualities for the fine line arts in maps was given - an exclusive digital approach for saving the cartographic heritage should be scrutinised and opened for discussion.

Introduction

Digital reproduction methods for cartographic products offer new possibilities in economical working processes and dissemination techniques. Due to digital processes the costs of reproduction are mostly reduced to working time and manpower. Material costs almost disappeared. On the other hand dissemination becomes supported by using the Internet and digital storage media. Never before, it has been so easy to distribute copies of cultural objects and to supply this copy with additional information or interpretations. These are the main arguments for digital technologies in cultural heritage. But what's about the storage costs instead of material costs, consequence of technology improvements or loss of digital data? A main scrupulosity against digital technologies seems to be its missing durability because of accumulation of various parameters like read-

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ability of data-format, accessibility of storage media and needed application or change of operating systems.
This contribution focuses on “hybrid” (analogue and digital) reproduction in context with its sustainability. With the understanding that a reproduction of the original map may deal as “working copy” and template for dissemination, the quality of this reproduction should be high as well as its long-term persistence should be ensured. Under these circumstances the original can be preserved and the copy will deal as basis for further discussion/work.

Importance of cartographic heritage and the map content

One main use of cartographic products seems to be decision support. Information retrieved should give some input in order to make the right decision e.g. in navigation. Generally the use of maps may be seen much wider, when thinking of maps as documentation tool for a specific spatial based condition by political or physical manner. Then historical maps may help to access past states and political situations, which help to expand the individual and social knowledge. Physical situations name topographic conditions like wooded areas, courses of rivers or traffic situations (to mention some of a long list). Wooded areas in historical maps may help to identify virgin wood and original vegetation. Traditional/natural courses of rivers may also be explored with old maps. Nowadays both topographic themes gain importance due to the results of human intervention on natural systems, which sometimes becomes expressed in floods and similar environmental hazards. Additionally the influence of increasing traffic situations on the environment can be studied by the development of topographic situations in historic maps.
A political situation often influences map design and content. Depending on politics, map signature changes because of ideally beliefs, military secrets or political influenced expression. For example, some parts in Germany possess various maps of the same region with multiple signature catalogues. The reason for the change of signature bases on the political system. Within communism some map-elements, like industrial zones, were considered to be top-secret. This secret status changed in history. Thus the comparison of maps of different time states will picture the appearance and disappearance of these map elements, although the real world object has always existed. An additional example by means of military secret depicts deliberate distortions of map sheets in order to hide real world topography or to express the political dominance of specific regions [some examples may be found in Monmonier 2002]. The results of politically motivated influence on map-making may be very misleading, if the influencing element (e.g. the political system) is not identified or simply unknown. But if the influencing element is known, then the expression of a map and the used signature as well as available metaphors may help to identify/interpret further mechanisms of this political system. To the same extend map-use may have impact on the signature of maps. For example, the replica of a Roman map, *Tabula Peutingeriana*, shows settlements according to hospitality and was designed as roll of paper in order to be used at travelling[1].
From a historical point of view, maps can tell a lot of passed and unknown circumstances, either by means of topography or the influence of policy, culture and pragmatics on the content. Thus the exploration of the past can be supported by accessing this documented information in maps for some extend. This is the main reason and importance for saving and disseminating cartographic heritage.

[1] http://www.onb.ac.at/

Overall considerations on sustainability of digital technologies

Latest technical developments make the reproduction and digitalisation of map sheets cheap and easy. This economic factor and an easy dissemination seem to strengthen numerous initiatives with the digitalisation of rare books and maps[2]. In most cases resulting products become available in form of CD-Rom or DVD. Basically the sustainability of these digital technologies has to be considered. Is digitalisation the right way to save printed heritage? There are several severe problems with long-term archiving of digital data concerning data format, operating system, used applications, media lifetime or hardware suppositions. All of these factors take effect on each dataset or media [Borghoff 2003]. The data format codes information and makes it readable for applications. This coding can be in binary and text-based (ASCII) form, depending on the algorithm of the code, which helps to reduce file size and make large information volumes accessible in a short time. Text-based formats can be viewed and manipulated in simple text editors, whereas binary formats cannot be decoded this easily [Henning 2000]. Binary formats will need some interpreter, specific software, which decodes and extracts information in any case (viewing, editing or using the information).

The application deals as interpreter for data formats and enables access to information with the programmed functionality. Depending on the functionality of this application and its related expense for development, various business models may allow a free available source code and its individual adaptation. These Open Source initiatives are a possible way to make today's applications accessible in future[3]. Instead of disseminating functionality only in compiled form (as executable file), an accessible source code also enables the compilation (the creation of an executable format) on various operating systems. In contrast to this "open" interpreter, proprietary software solutions are most spread, because companies are not be keen on distributing their source codes, which normally forms their source of invest and income. As result these interpreters/programs depend on the policy and ongoing work of the company. Long term accessibility cannot be guaranteed in these cases. The operating system forms the basis for executing a file/program that interprets the coded information. New developments in operating systems adapt to new hardware components. This may cause incompatibilities with existing interpreters. In many cases old interpreters are not usable on new operating systems anymore. For example executables for the commodore C64 system are not usable on actual computers. Latest developments show some solution for this problem of incompatible operating systems: virtual machines or emulators. This technique / software allow embedding an operating system in another one and using it like a native system[4].

Media lifetime spans various aspects of computer development. On one hand media lifetime concerns durability of the media itself and on the other it may be related with the development of hardware devices. Durability of the media itself depends on used materials. For example the media CD-R is composed of a transparent carrier-layer and the reflecting storage-layer (with a simplified description). The durability of data on the storage-layer depends on its chemical and physical consistency. Chemical (change of emulsion due to sunlight or chemical influence) and physical (destruction of parts of the surface) deformations can cause a complete loss of data. In addition the thickness of storage-layer emulsion is a gauge for its damage sensibility. But within the pro-

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[2] http://www.octavo.com/

[3] http://www.opensource.org

[4] http://www.emulinks.de

duction of CD-R this thickness varies. Even the lifetime of one single product cannot be easily appointed because of the changes of storage-layer thickness [Borhoff 2003].
The ongoing development of hardware devices results in specific hardware suppositions in order to play specific media. While in the late twentieth century a floppy disk was the most mobile storage device and magnetic tape devices were used to store data masses, few years later, ZIP disks and magneto-optic media embossed data storage. Nowadays flash disks with USB connector as most mobile and sizeable storage media and DVD as the most commonly used media for large data amounts shape data storage activities. This development of storage devices, within the past ten years, makes the rapid change of devices clear. Generally only in few cases magnetic tapes are used for storage furthermore. Data on this media have to be copied to the latest device and media generation in order to be accessible. The same way of copying has also to be used with hard disk media, which almost double storage capacity every two years [Bergeron 2002]. In addition redundant storage management for sustainable data access should be considered because of drive failures and occurring damages. These five almost independent factors give a coarse overview on the influencing factors on sustainability of digital data. Of course traditional archival considerations of shelf life, temperature and humidity are still valid because these "traditional" factors influence media/storage-layer lifetime. Resulting from the technical dependencies and the mentioned state of the art methodologies to overcome accessibility problems, it has to be stated that digital data seem not to be a place for safe custody of cartographic heritage (by traditional means: storing data and accessing these after some decades or centuries) [Dörr 1999]. Digitalisation would form no appropriate solution, if the task of a sustainable heritage management would be defined by solely archiving. Too many influencing factors affect the life-time and accessibility of data. Additionally digitalisation methods are developing very fast. The resolution and quality growth is almost as high as the growth of storage capacity. But when we think on transmission of knowledge, to recollect historic information and to build up consciousness, most of digital characteristics can support these action items. Especially the lossless reproduction of digital data, its easy dissemination and extension with multimedia components are the main important supportive tools of cultural knowledge transmission/communication. Making the public conscious of cultural heritage seems to be as important as archiving. Growing information inputs in everyday life by various media (TV, advertising, ...) cause some kind of visual deadening [Müller 2003]. More and more it becomes harder to transmit "important" content with less effective methods. The intense use of multimedia may help to overcome this cleavage of effectiveness. The purpose of being effective is to establish a cultural knowledge, which can help to extract specific information within this knowledge. For example, if the existence of a specific content is vaguely known, it is easy to search for it even in large datasets. Otherwise the aimed extraction of specific data within growing masses of unknown data/content mostly leads to unsuccessful results. Concluding these overall considerations on sustainability of digital technologies leads to two main tasks of digitalisation/digital data: a lossless reproduction of copies and support of effective dissemination. The digital reproduction seems not to be an achievable object at the moment. Thus the focus of archiving and preservation should be on the original object. An essential need for digital reproduction may be seen in the creation of digital working copies, which depends on digital or hybrid reproduction methods.

Digital reproduction technique

Similar to analogue reproduction techniques, sensors, light sources and the source-object are needed for digital reproduction. Whereas analogue reproduction uses sensitised film material and various filtering mechanisms in order to gain colours of the artwork, digital techniques depend on the sensibility of the used sensor. The technical formation of scanners mostly depends on the characteristic of sensors. Generally CCD- or CMOS sensors are sensitive to a wide bandwidth, reaching from 400 nm to 2400 nm, which has to be restricted to about 700 nm with specific elimination filters. Even though, the sensors are more sensible to the red contingent. This high sensibility in red and near infrared causes loss of the blue contingent when monochromatic reproductions are made. The use of blue light sources is one simple solution to counter this effect.

Coloured reproductions require a much more detailed filtering, which results in various arrangements of sensors. In contrast to film material, which uses three filter layers for the absorption of the colour spectrum, most of sensors have to be filtered three times, which results in a three-pass system, or one pixel is calculated by merging 3 sensor elements, which is called one-pass system. It can be clearly seen that a one-pass system needs a three time higher density of sensors in order to come to the same resolution as the three-pass system. Various dispositions of the sensor elements result in different effects of the resulting picture (e.g. diagonal orientation like the Super CCD of Fuji[5]. The creation of the X3 CMOS sensor by the company Foveon[6] in 2002 presented the possibility of imitating film by combining the filtering process on one over the other. At the moment the CMOS sizes are still too small to be used for high quality map reproduction.

Large format scanners (flatbed scanners, area- or plot scanners) use three rows (tri-linear scan sensor) or only one row of sensors. This row either uses a turn round prism or LED light sources (LIDE technique) for filtering. The one row system generally is called Contact Image Sensor (CIS). It uses no lens to focus sampled data on the field of sensors. Thus it is almost free of maintenance [Krautzer 1999]. Latest developments show effective resolutions up to 2400 dpi. Camera scanners can be described as digital "film packs", which use the main components of flatbed scanners (row sensor, spindle, stepping motor, A/D modifier and cache). In most cases the sensors are built in cases that are used similar to a film holder. The principle arrangement of sensors can be as row (for high quality reproductions of art and still life) or furthermore as array (for photographic tasks where fast one-shot scans are used). The use of camera scanners was thought to be as non contact scanners, which can use the whole sensor capacity for recording. A general size of the sensor row in camera scanners is about 7 centimetres with 8500 sensor elements. Latest available developments (like at company Cruse[7]) present systems including artwork holder, light system and camera scanner with a fixed resolution of 10500x15000 pixel on a maximum object size of 40"x60" (approx. 120x160 cm).

After a simple calculation of resolution large format scanners would be appropriate for digitising large format objects with fine details, like copperplate prints have. But when working with cartographic heritage, ancient handwritings or vintage books, any contact with the object is critical and may damage it. The kind of contact reaches from skin (bacterial and acid level influence) to mechanical (human and machine influence). A classification of contact and contact-free reproduction techniques/scanners seems to be useful. Large format scanners use some kind of sheaves to transport the artwork over the row sensor. Its mechanical influence on the surface of the artwork makes this system useless for unique historic objects. In the same way drum scanners can be seen: the artwork, which has to be pliable, is fixed on a cylinder from where the sensor reads data by rotation.

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[5] http://www.fujifilm.de/spass_1189.html

[6] http://www.foveon.com

[7] http://www.crusedigital.com

Camera scanners follow the concept of contact-free reproduction as it was used with analogue techniques. In this case the projection on the film plane or sensor plane underlies possible distortions of the camera lens, especially geometric and chromatic aberration. This influence has to be considered in further analysis of reproduction quality, especially when no specific reproduction lens is used.

Hybrid reproduction issues

Equipment for reproduction has been subject of intense investigation in the last century. Results were high quality lenses almost without aberrations, large camera bodies with various adjustment possibilities for filtering and geometric equalisation. It seems to be very unwise to get rid of these high tech developments only because it works mechanical, not digital and seems to be out of date. Considering available resolutions within contact-free scanners may bring up the need for better alternatives. One of the highest developed scanners peaks at 10500x15000 pixels for the sensor and about 160 x 240 cm for the object holder. Using this maximum extend for a simple resolution equation results in approximately 240 dpi (maximum pixel divided with maximum extend of object). This value is at any rate too little for high quality reproduction in scale 1:1. Reducing the object size to an average of 84x119 cm (A0 format) it leads to a resolution of approx. 320 dpi. A further limitation to 42x60 cm (A2 format) ends up in approx. 635 dpi. The last two values are sufficient for reproductions of pictures, which need about 300 dpi in the digital reproduction process in order to get rid of visible fractals (pixel structures).
The question for alternatives to actual existing digital reproduction systems leads to the design of hybrid methods. These desirable methods should combine traditional/analogue techniques with digital ones. The aim should be higher resolutions, sustainable and cheap accessibility and still performing high quality reproductions (sufficient for scales in 1:1 or even larger).

Quality issues when reproducing line art

Useful quality descriptions focus on the planned aim of reproduction process. The end size of reproduction is the measure for needed resolution. For pictures a minimum of 300 dpi at the resulting size is needed to get rid of raster fractals (visible pixels of the digital image) and to have enough information for the rastering process in print, that uses several pixels for one printing point [Priess 1995]. For line art the minimum value is much higher: 1200 dpi at the resulting printing size are needed for bitmaps (black and white images) or lines in order to make raster "steps" invisible [Limburg 1997]. At this resolution the size of the pixel is so small that two pixels cannot be differentiated from one another. On the other side resolutions of print and printing films have to be considered. Within print, lines should not be smaller than 0,3 pt to assure constant line size. Smaller values will result in broken or uneven lines depending on the used paper. The resolution of printing film, which is the starting material for the production of printing plates (assuming that the traditional reproduction process is in focus and not something like "print-to-plate", where digital images are directly sent to the printing plate), is about 1000 lines/mm at a hard gradation (contrast 1000:1). This value may vary with gradation, used chemicals and film emulsion. Compared to the postulated value of digital line art, which is approx. 50 lines/mm (1200 dpi), printing film offers enormous potential of resolution for further enlargements.
These deliberations presuppose a chosen end size of reproduction. But what if this size cannot be determined because a prospectively use cannot be specified? This would be the case, if digitalisa-

tion is done for archiving purpose. Then either an assumed size for further use has to be specified or a method providing potential for a wide variety of usage has to be chosen.
An appointed end size often is calculated with available storage media and its capacity. Thus available storage media seem to dimension a possible resolution beside hardware configuration (scanner) or operating system limits. Recalling capacity development where storage media almost double their capacity every two years should result in reviewing any decision made, especially when digitalisation projects with a working time of several years or even decades are concerned.

The intermediate product – a working copy

A digitalisation method with no superficial constraint of further usage may have to use a hybrid approach. This approach then follows traditional reproduction in order to obtain an intermediate product in form of printing film. The intermediate product forms the starting point for digitalisation, which may be adapted to actual scanner developments as well as to prospective use of the digital format (adaptation of quality). Additionally this intermediate product presents the working copy for content based analysis (media based analysis, like examinations of material, still will require the original artwork) and therefore redundant archiving (the original artwork and the intermediate copy) should be suggested. This procedure of redundant archiving is a frequently practised method by libraries to save the content of their inventory. The favoured film material then is "large format" microfilm, which lifetime can be estimated with about 500 years under controlled circumstances[8].

Testing various set-ups

The request for hybrid methods resulted in two technical set-ups, which seemed to be promising by reviewing literature and theoretic considerations. The idea of the first one was to combine traditional reproduction technology with low-cost digital scanning technology. The low-cost scanner was argued with an easy interchangeability for future developments as well as providing sufficient quality respecting operating system limitations. Similar to the construction of scanner cameras, the flatbed scanner was built into the film-plane of the camera. Possible misalignments of the scanning plane and camera's film plane were no subject of investigation. For the first attempt realizability and its imagery quality should be proven. The second set-up was aiming to achieve an intermediate product in form of printing film, which then should be used for digitalisation. The scanning process, similar to set-up one, should use a low-cost flatbed scanner in order to assure easy interchangeability with further scanner developments. Misalignments and possible geometric distortions were also no investigation of this attempt, but should be considered by a critical discussion of the results.
The traditional reproduction technology was represented by various two-room cameras. Because not all instruments available were immaculately working, cameras had to be changed. The main problems were rough edges of the bellows unit, which may have had negative influence within the second set-up – the exposure of film. Cameras like these [Jüptner 1987] are rarely used, which means that necessary corrections are not made because these are too expensive or replacement parts are not available anymore. Both set-ups suffered from limitations in file size by the operating system. In a 32-bit Windows-based computer the maximum file size is limited to 2 GB. New

[8] http://www.kodak.com, http://www.ilford.com

64-bit systems support file sizes up to 4 GB[9]. The attempt to use a 64-bit system was overruled by missing support of the scanner and software.

The results, comparisons and a glance on file size

This section presents the results and enlightens disadvantages of the compared methods. Fortunately a direct comparison with a camera scanner was possible throughout the project HYREP and the help of the Federal Office of Metrology and Surveying. The inquisitional material was formed by copperplate prints of the 18th century displaying some parts of Austria. These prints on one hand contain old riverbeds of Upper Austria, thus some important content for an interested planning consortium is available, and on the other hand are formed by very fine line artwork within the rivers, woods and object symbols, which enables the direct comparison of scanning techniques.

Set-up one, the mounting of the scanner in the film plane, reached no results, although the mounting of the scanner caused no problems. The reason for the failure was the inconsistency of the latent picture on the scanning plane, which depended on the material to catch this picture. Additionally the light intensity of the latent picture was too slight, which resulted in enormous pixel noise within the digital picture (see picture 1). This method may be improved by rebuilding the scanner and replacing the material of the scanning plane (catching material) to a similar fabric as it is used in camera scanners. Anyway it has to be seen that the catching material has direct influence on the result: if the surface is rough, high scanning resolutions will also produce the roughness – if the surface is smooth, the latent picture will be too slight for scanning.

Set-up two, the production of an intermediate copy before scanning, resulted in a set of films originating from the historic submittals. One main difficulty was to find a well working reproduction camera, because this technique is argued to be old fashioned and thus it is not worth to be mended. At least one camera was available and accessible at the Institute of Cartography at the Technical University of Dresden. The production of the film material, the intermediate copy, is characterised by exposure time, filtering, film material and used chemicals. The exposure time influences the thickness of lines on the film. The correct exposure time will produce very fine details also of the finest lines as well as no "growing" of thick lines, which is some kind of blooming effect. Filtering enables the removal of coloured parts so as to expose only the line based content on the film. The film is one factor that defines gradation and thus the number of gradings for coming from black to white. In addition this gradation is, for some extent, casting the resolution of the film. High contrast results in higher resolutions, which bases on the emulsion crystal structure [Hübner 1986]. The chemicals for film development and fixation also have some influence on the gradation. Depending on the reaction of the developer chemicals with the exposed emulsion on the film, contrast may be higher or lower.

Picture 1: Result of scanning with a mounted scanner in the film plane.

[9] http://www.microsoft.com

In order to have manageable analogue copies for the scanning afterwards, the size was reduced to 50% of the original map sheet. A negative consequence on resolution quality was not expected, because all considerations resulted in having enough potential with hard grading film. The scanning process of the intermediate copy generally offers comprehensive influence on gradation again. This process aims at employing all usable storage units (bits and bytes) and having almost no loss of information between the original (intermediate copy) and digital copy. Resulting from these processes it has to be stated that only existent information on the original can be digitised, which means that failures of the analogue film exposure cannot be solved within the digital process. For the realisation of the digitalisation only 2400 dpi were used, which is the half of the full optical resolution. The adjustment to the original size of reproduction camera reduction then resulted in 1200 dpi of the scanned image. An example of this method can be found in picture 2 at the right side.

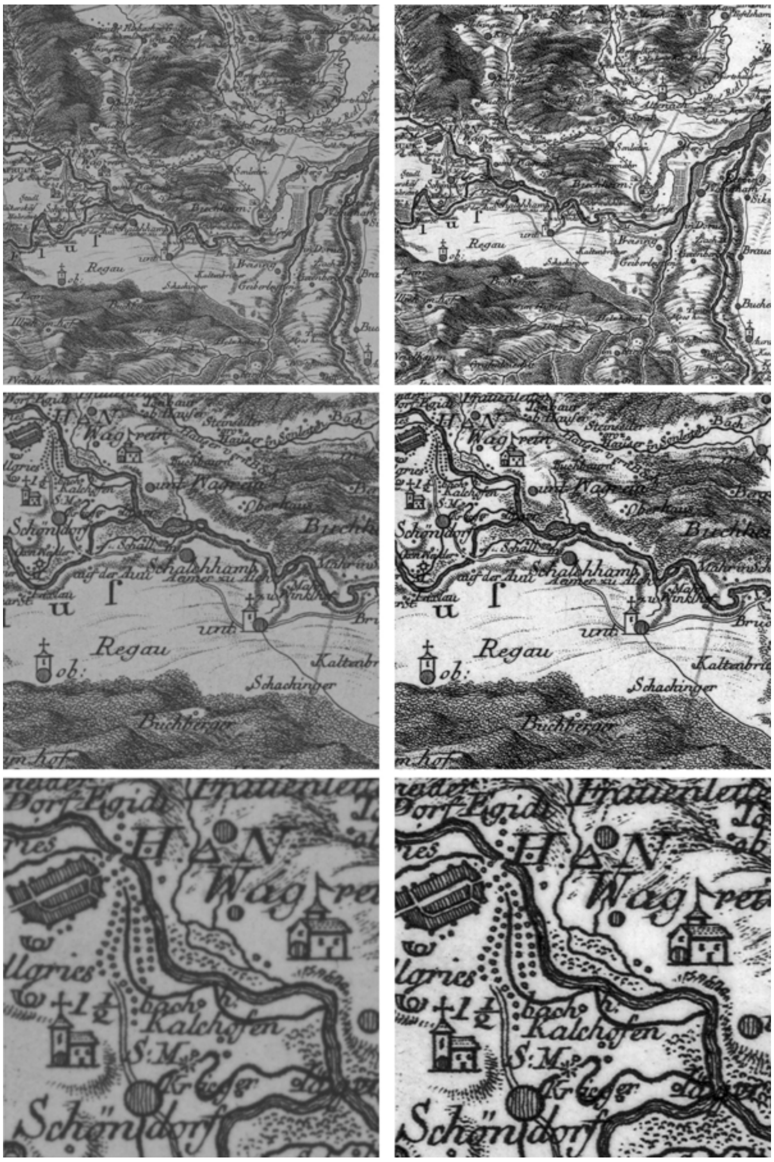
The same copperplate prints, which were used for the hybrid process, were the source for an actual digital reproduction process. For this process a camera scanner with a 10500x15000 pixel resulting file size was used. The framework for digitalisation was to record one map sheet in one shot. The creation of mosaics and digital mounting in a post-processing step certainly would have produced higher resolution, but would be not adaptable to masses of data from an economic and archival point of view. With this framework the maximum acquirable resolution was 400 dpi. One example of this process is shown in picture 2 at the left side. The direct comparison of the digital state-of-the-art process with the hybrid method of scanning the film can show up visual quality differences (picture 2), especially when details become enlarged. Thus this picture shows a section of 10x10 cm, 5x5 cm and 2x2 cm. This result can verify the simple resolution calculation made for the assumption that digital reproduction cannot provide enough quality for fine line art (made in section 5) at the moment.

The genesis of picture 2 should be shortly explained at this point, because digital procedures may give the potential to distort objective results and to produce outcomes that support argumentation. Both results left side as well as right side, are “as is” pictures. This means that the achieved result was not further processed by filtering or changing brightness and contrast! It may be that the camera scan (left side of picture 2) would be more brilliant by changing the contrast, but this would influence the direct comparison. The digitalisation of the intermediate copy (right side of picture 2) seems to have a higher contrast. This is the result of the precise adaptation of the scanning process and not of a post-processing step. A post-processing step lessens information that is stored in pixels and thus should be avoided.

The starting point of picture 2 was the highest quality of the camera scanner (which is still the quality of this digital image). From this, sections were extracted, enlarged and put to the same extent in order to visualize quality loss. The same steps were made for the hybrid result, for which the extractions of 10 cm and 5 cm had to be reduced in size in order to use the same area on the sheet.

Resuming and further aspects

As result of this investigation it can be stated that traditional/analogue methods still have an important role for saving cartographic heritage. It becomes important to differ between use oriented processes, where digitalisation seems very useful for dissemination purposes, and archiving oriented processes, whose results should be accessible also in far future. The non economical way of producing intermediate products on film, which again uses material, time and manpower, can only be argued with the “safe way”. The intermediate product serves as working copy and enables a strict archiving of the original source. Additionally its lifetime ensures working copies for a far future. The digital way of reproduction seems to be very economic. Often the complexity of effort for archival purposes cannot be seen (media storage, device availability etc.). A productive and pragmatic applicability for archival (long-term) purposes has to be worked at in order to open rapid digitalisation, sustainable archiving and long-term dissemination for the digital cartographic heritage.



Picture 2: Direct comparison of camera scanner (left side) and hybrid method (right side).
This picture is reduced in size for publication purposes.

Independent from reproduction processes all participants in cartographic heritage have to be conscious about the importance of maps and uniqueness of original material. Throughout centuries reproductions and facsimiles were made and often are the only source for extracting historic topographic or political contents. Their status transformed to an original! But still some questions, e.g. concerning the material and production technique, can only be answered with the source material.

Acknowledgements

The author thanks all helping participants for their support in this project. Special thanks go to the Federal Office of Metrology and Surveying, which made the direct comparison with a state-of-the-art scanner possible, the Institute of Cartography at the University of Dresden, which provided film material, helping hands and access to the camera, and especially to the City of Vienna, whose funding of the project HYREP, H 1071 / 2004, made this analysis possible at all.

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