Cartographic traditions and the future of digital maps: A Finnish perspective

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In this article, we examine changes and trends in Finnish cartography using examples from the history of map-making and from our own empirical landscape research. Three major issues of data sources, combined uses of spatial data, and interactive spatial information services are emphasised. The Finnish map-making tradition illustrates well the close linkage between cartography, society, and surveying techniques. Sweden and Russia influenced the mapping traditions until the twentieth century. Geographers published the world's first National Atlas in 1899. Comprehensive state-run mapping has characterised Finnish cartography from the early twentieth century onwards. New techniques and data have modernised map-making, but the recent convergence of automated positioning, wireless communication, and digital spatial information handling are currently creating previously non-existing ways of cartographic communication. Spatial or geographic information systems enable the collection, management, and analyses of spatial information for a wide variety of uses. The contents and means of delivering cartographic information to the public is broadening and new digital spatial information services are designed for resource management, retailing, and tourism. A critical examination of data quality, visualisation, and the ethical and sociological consequences of these trends are needed to sustain the Finnish cartographic tradition in the Information Age.

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Introduction

Map users in the twenty-first century will witness changes in the visualisation and application of spatial information. The convergence of enabling technologies, such as automated positioning, wireless communication, and digital spatial information handling, will permit the development of previously non-existing implementations of cartographic communication (Burnett & Kalliola 2000). The adoption of cartographic developments in mainstream society must not, however, be viewed as a simple deterministic cycle of technological wonders begetting societal benefits. Much of the public discourse regarding future cartographic tools is filled with uncritical enthusiasm. Graham (1998) cautions against such stary-eyed utopianism. The role of the scientific community, including cartographers and those working with the perception of space and the human context, is to critically investigate the interactions between digital spatial information and society (Kalliola et al. 2001).

The evolution of cartography as spatial information communication is driven by changes in societal need and in the state of measurement and presentation techniques (Robinson et al. 1995; Keates 1996). Throughout their evolution, maps have increased their agency for conveying information and expanded into new societal uses that include – but are not restricted to – teaching, geopolitics, military needs, resource exploitation, logistics, marketing, and tourism. While the necessity to communicate cartographically in these forums will remain, developments in digital cartographic communication will add new rings (socio-technical artefacts) to an already existing chain of past advances in map-making (Mellaart 1963; Bagrow & Skelton 1985; Campbell 1993;

Dorling 1997). In this article, we take the perspective that these new artefacts will draw heavily from conventions established through the history of cartography while adding unforeseen models of cartographic information exchange.

Undoubtedly, digitalisation has already induced important changes in cartography. In the late twentieth century, the introduction of remote sensing and Geographic Information Systems (GIS) were quickly adopted for map production tasks worldwide (Morrison 1989; Artimo 1994). GIS has made it easier to reproduce, update, customise, cross-analyse, and perform a variety of other spatial operations and analyses (Aronoff 1991; Laurini & Thompson 1992; Jones 1997; Clarke 2001). In the majority of these applications, however, GIS only help users gain speed and efficiency in their work. Thus, the view of GIS as a revolutionary approach to cartography is partly a myth. More specifically, it is a myth, if developments in society are ignored in favour of one-sided views of technology 'impacting' society.

The work of the Finnish geographer J. G. Granö (1930, 1997) is an illustrative example of a pre-digital cartography, where a highly organised landscape analysis system was developed half a century before the introduction of the GIS technology. It is worthy of note that even with the 'advanced' GIS tools, good geographic analysis has remained true to the Granö tradition. Granö's synthesis was a delicate process of data combination, fulfilled with a careful synthesis and analysis of landscape regions. The presence of this care and attention in contemporary cartography, whether in creating tourist information systems or landscape-ecological assessments, lies at the core of balanced use of modern geographic information.

In this article, we examine cartography as a co-evolutionary process of society and technology. We use examples from the history of cartography in Finland and from our own empirical landscape research on the island of Ruissalo in southwestern Finland (Vuorela 2000, 2001; Burnett & Toivonen 2001). We examine five themes: the history of cartography in Finland; new digital data sources; issues arising from data combination; new digital cartographic services; and digital map reliability.

Landmarks of cartography in Finland

Finland can be considered one of the frontline countries in the evolution of map-making over the past few centuries. This situation results partly from a fruitful mixture of versatile map production efforts and traditions drawn from two neighbouring countries, Sweden and Russia. They impacted Finnish map-making tradition from the late seventeenth to the twentieth century. More precisely, the national trends in map-making illustrate well the close linkage between cartography, society, and surveying techniques.

The centuries-long influence of Sweden resulted in a strong map-making tradition in Finland. The introduction of triangulation and plane table methods to map-making in the seventeenth century improved the accuracy of maps greatly (Niemelä 1984: 2). As Finland was economically and strategically important to Sweden, tax collection and implementation of land reforms were planned with the aid of the early maps. The Swedish King initiated mapping in Finland during the 1630s. These mappings were targeted to measure the extent and quality of arable land and meadows and became known as *geometrical* or *geographical maps* (Lönborg 1901; Johnsson 1965).

During the period when Finland was a Grand Duchy under the Russian Empire (1809–1917), new trends and styles were adopted in map production and design. The Land Survey administration still developed along the lines of the Swedish system, however. Overall, the progress of cartography slowed down during these years, but military mapping was carried out both by Finns and Russians (Niemelä 1984: 2). The previous mapping by the Russian Topographic Service (in eastern Finland, part of Russia before 1809) was extended to the rest of the country, mainly south and west. Between 1870 and 1917, a series of maps was created to cover large parts of Finland at scales of 1:21 000 and 1:42 000 (Gustafsson 1932, 1933: 86–88). Finland thus became topographically described relatively early compared to other European nations (Paulaharju 1947; Niemelä 1984, 1998). These Russian Topographic Maps constitute important documents of the time, as they include typical features of the present-day basic maps, such as arable land, meadows, roads, and buildings in addition to landforms.

Maps also became a valuable means of characterising Finnish identity and nationality at the end of the nineteenth and beginning of the twentieth century. As an effort of geographers, the first edition of the *National Atlas of Finland* was published in 1899. This first national atlas in the world represented Finland through a variety of thematic maps showing characteristic features of the country (Niemelä 1982: 170). Immediately following Finland's independence in 1917, map production developed into an organised, state-run mapping system, where the Military Topographic Service carried out military mapping and the National Land Survey of Finland (NLS) other mappings (Lyytikäinen 1983: 448). Until the 1940s, two main products, the Parish Map and the Topographic Map, were produced. Production of the former had started already in 1825. By the time the program terminated in 1950, these maps had covered approximately 27 percent of Finland (Niemelä 1998: 27). Due to their long production history the parish maps vary, reflecting changes in printing techniques and visualisation. Topographic maps were produced between 1917 and 1947 (Niemelä 1998: 40).

A significant change in the underlying mapping techniques occurred in the 1930s. Instead of the plane table measurements, mapping was now based on aerial photography. The role of remote sensing has been central ever since. As remote sensing gained wider use in map production, the National Land Survey renewed its maps during the 1940s. The parish map and the topographic map were combined to produce the Basic Map of Finland (1:20 000) (Niemelä 1984). Basic maps included general information about the landscape and were designed for a large audience of both professional and accustomed users (Niemelä 1998: 54). The mapping was based on aerial photography acquired at a scale of 1:10 000 and cartographic visualisation was based on a six-colour printing.

The social and technical change that drives cartographic evolution is propelling changes in cartographic models, methods, and maps, and putting pressure on large governmental organisations such as the National Land Survey of Finland. The implementation of computer technology and new storage systems for geographical object locations and attributes have diversified the possibilities of designing and making maps. Instead of storing spatial information statically on a printed map, location-related data is increasingly stored in digital Geographic Information (GI) databases and further visualised in printed form or as computer display maps (Artimo 1996).

The 50-year-old Finnish Basic Map production system has had to adjust to the new developments (Artimo 1996; Niemelä 1998). From the 1970s onwards, the map production chain has been changed into a GI-based storage and visualisation system (Niemelä 1998). Currently, the production of the Basic Maps relies on digital databases (topographic database, map database) with thematic or attribute information attached to vector format geographic objects. The accuracy of the topographic database varies between 1:5 000 and 1:10 000. They are updated every 5–10 years, except for roads, which are updated every year (Niemelä 1998: 134).

Due to these technical changes, the NLS is providing customers with new product types and map visualisation options. The Basic Map can be purchased either as a printed map (in Finnish, *maastokartta*) that introduces a different set of colours and symbols compared to the previous Basic Map, or as a digital vector format Basic Map Dataset (*maastotietokanta*), which can be adjusted to a customer's needs. These data are available for manipulation in the end-user's computer system. Similarly, Basic Maps can be purchased in raster format (*Perus-CD*), where different thematic information layers can be explored.

New cartographic data sources and processing

Developments in the technology of new data sources and processing methods tend to be adopted into mainstream use approximately a decade after the first prototypes are built. Recent improvements in data collection technology in the fields of surveying and remote sensing are changing cartography. In survey science, satellite-based global positioning systems (GPS) and hand-held infra-red (IR) electronic measuring devices have increased the accuracy of traditional surveying methods. Expensive ground-based GPS survey systems that make use of differential GPS with kinematic and ionispheric corrections can claim centimetre accuracies. GPS systems are also used in the creation of digital orthophoto mosaics. The accuracy of consumer GPS systems improved in May of 2000, when the US government removed the signal accuracy degrading "selective availability." GPS instrument manufacturers now produce instruments that track both the American GPS satellites and the Russian GLONASS satellites. Future reliance on these foreign systems may decrease at least in Europe, where the national governments within the European Union have recently pledged support for a European satellite navigation system called Galileo (Ochieng & Chen 2000).

In the field of remote sensing, several new digital satellite, airborne, and terrestrial systems have been, or will soon be, deployed. There are tens of satellite-based systems already in operation that can provide useful data for cartographers. These include Landsat and SPOT with nominal ground resolutions between 10 and 30 metres, and IKONOS and EROS-1 at 1 metre. Some 30 satellite launches are planned for 2001. They focus on earth observation missions, most being military or weather satellites. Several, however, will collect data of interest to the civilian and governmental mapping markets. These include the first sub-metre resolution satellite-based sensor (Quickbird2, 61 cm) and the first satellite-based imaging spectrometer (ARIES-1). A full summary of space and remote sensing research and industry projects conducted under the recent five-year TEKES (National Technology Agency) Globe 2000 and Space 2000 programs is given in Fabis and Gudmandsen (2001). Fabis and Gudmandsen (2001) estimate that approximately 20 research organisations and groups, as well as several companies, participate in research activities that focus on increasing Finnish space-technological capacity and remote sensing expertise. Airborne data acquisition systems that are being developed or are in operation in Finland include digital cameras/semi-automated image mosaicking (Holm et al. 1999), the AISA Airborne Imaging Spectrometer (Okkonen et al. 1997; Mäkisara et al. 1997), an airborne SAR (Kallio et al. 2000; Martinez et al. 2000), and a number of companies and government agencies that produce digital orthophotos (e.g., FM-Kartta Oy, NLS of Finland). In the terrestrial mode, video cameras are being installed and connected via telecommunications networks to provide real-time geographic information via the Internet (Travel… 2001).

The range of data processing tools and methodologies being developed in Finland is enormous and only a sample is mentioned here. The modern analogue to the topographic map is the digital elevation model (DEM), created either by stereo-photogrammetry (using digitised aerial photography) or, more recently, directly from LIDAR (LIght Detection And Ranging) height measurements and scanning laser (see Samberg 1997). DEMs have many uses, from modelling landscape processes to image drapes, but perhaps the most useful, cartographically, is the creation of geometrically corrected aerial photography, or digital orthophotography. Orthophotos can be used like maps, but they contain more information as they have not been generalised. The NLS of Finland creates its DEM from the contour lines and coastline elements of the Basic Map by triangulated network interpolation into a grid model where the grid cell size is 25 x 25 metres.

Mosaics of aerial photographs and video or digital camera data are increasingly used as GIS base maps. The mosaicking of images and subsequent atmospheric correction procedures are challenging data processing steps, which Finnish scientists have explored thoroughly (Holm et al. 1999; Pellikka 1998; Pellikka et al. 2000). Holm (1995) has taken the processing of stereo imagery a step further, reconstructing complete image models (buildings and trees as well as the elevation model). Elevation models may also be produced by using scanning LIDAR (scanning laser) data. Using a combination of aircraft XY and altitude position (GPS) and attitude (GPS or attitude sensor), LIDAR data can be accurately corrected to ground heights above sea level. The difference between the NLS DEM and the LIDAR DEMs is mainly in regard to resolution: the latter is able to provide sub-metre 3D surveys. Scanning LIDAR data has been used in the modelling of buildings, utility line corridors, and trees (Ziegler et al. 2000).

A great deal of mapping research in Finland has focused on delimiting the boundaries and deriving the attributes of trees and forest stands from remotely sensed data. Examples of this type of analysis include the *k nearest neighbor* (KNN) method of forest inventory developed at METLA (Finnish Forest Research Institute) (Tomppo 1996, 1998), individual tree crown mapping, and automated stand mapping using segmentation. CD-Figure 1 shows two examples of these applications. In the first example, the mapping of individual tree crowns is intended as the first of several semi-automated steps that will take combinations of remotely-sensed and field data and produce forest habitat compartment maps (Burnett & Toivonen 2001). The second example of forest mapping shows 1.6-metre ground resolution AISA data of a forest scene segmented into polygons in a semi-automated fashion using algorithms developed at METLA (Haapanen & Pekkarinen 2000).

In summary, several trends in new data sources and processing can be identified in Finland. Firstly, improvements in technology (optics, electronics, computers, etc.) are producing new geographic information data sources. Depending upon their cost, some of these sources are becoming available to the general public (e.g., terrestrial video data and digital map data from the NLS). Secondly, remotely-sensed images are used increasingly in combination with vector-form map data. Most of these data sets, however, are either too expensive or require a large amount of expert processing. Thirdly, development of data processing methods and applications are related to increases in the number and quality of data sources. This development is cyclical in nature: applications create markets (demand), which drive the development of new data sources. These, in turn, create application potential. Finnish scientists are leading the way in many processing research themes, especially in those related to mapping.

Possibilities for flexible data combination and visualisation

It would probably have been unimaginable to a seventeenth-century surveyor to see the potential that digital systems give to the usage of old maps or to realise the value of these maps as information sources to present-day researchers. Especially for landscape researchers, old maps are the primary representations of the past features and characteristics of the landscape. Maps can be used in a broad spectrum of landscape research, from ecological and geomorphological to political, social, and cultural topics (Dickinson 1979; Sporrong 1990; Roeck Hansen 1996).

Maps have been a major source of inspiration to study landscape evolution from the historical times to the present-day. Even though maps are widely used in landscape research, in few countries the variety and availability of maps are as good as in Finland. Due to the rich history of mapmaking in Finland, the possibilities for landscape change research are manifold. Further, combined uses of maps have expanded, since digital tools enable transformation of old maps into digital spatial data. Similarly, demands for a careful assessment of their information contents have increased. Most often, the transformation of printed maps into geographic information requires unique solutions that differ from those used in remotely sensed data transformations (Vuorela et al. 2002). Visualisations in CD-Figure 2 illustrate how combinations of multi-temporal GI, originating from different sources (e.g., remotely sensed images, old maps, written records), can reveal interesting links between valuable landscape features and other environmental factors, such as topography, soils, and land uses (see Vuorela 2000, 2001).

Combining landscape information to explain distribution of oaks

The current distribution (1998) of old oaks on Ruissalo Island in southwestern Finland (CD-Fig. 2A) is fragmented within the woodland areas. This pattern is very difficult to explain unless both land use history and natural edaphic factors are taken into account. Most of the oaks seem to be concentrated on slopes (CD-Fig. 2B) and near edges of the wooded areas (CD-Fig. 2A). The lack of oak both from the upper parts of the hills and from low clay areas can be explained in the following manner: soil conditions affect species distribution profoundly. Oaks do not grow on the tops of the hills because they are too rugged and nutrient-poor. Edaphic conditions thus determine the upper margin of the oaks. Similarly, oaks do not exist in clay areas, because these areas have been in agricultural use (arable land, meadows) continuously after their exposure from the sea (land uplift). Therefore, the lower margin of the oaks shows adaptation primarily to land use changes.

The key to explaining the distribution patterns of oaks is related to the natural site conditions and land use changes of the slope areas. Slopes can be identified both as edaphic and land use transition zones. Here, clay deposits change into rugged bedrock areas, but the change is not always abrupt and different types of shallow moraines can be identified within the bedrock areas. These often provide suitable sites for an oak to grow. Slope areas have, however, experienced fluctuation and shifts in land uses over time. Oak was a typical tree on meadows and pastures that were characteristic to gentle slopes (CD-Fig. 2C) (Ekqvist 1846). Since the end of the animal husbandry agriculture, some of the wooded meadows were cleared for agricultural land. Others remained wooded and changed gradually into different types of woodlands, which have been lightly managed over the last century (CD-Fig. 2D). Altogether, the present-day distribution of Ruissalo's large oak individuals reflects the natural potential of the sites convolved with land use variations at work over hundreds of years. In other words, oak woodlands reflect the diversity of natural and human induced environmental factors that have evolved and changed through time (see Vuorela 2000, 2001).

The Ruissalo example shows how maps provide a unique information source for reconstructing, describing, and understanding the development of landscapes through time (Tollin 1991; Skånes 1996; Cousins 2001). For many applications, there are needs to combine data originating from different sources (e.g., information services). Visualisation of cartographic (spatial) information is based on the combination of data within the shared coordinate reference system. The digital data format makes combining data technically relatively easy. Many data types (like old maps), however, require specific solutions to data format transfer and spatial adjusting (accuracy). Similarly, different digital media (e.g., mobile phones, laptops) require unique solutions to visualise data. Further, as information content and its representation are so variable in different data sets, conversion into GI should be a selective process where spatial, temporal, and thematic data properties are evaluated (Faiz & Boursier 1996; Richardson 1996). An illustrative example of the possibilities and restrictions of data combination can be found from Vuorela et al. (2002), where a collection of nine maps were evaluated from the perspective of combining them in a GIS to perform landscape change analysis. It is possible to improve the usability of GI originating from many data sets, if an attempt is made to control and adjust the spatial, thematic, and temporal accuracy of data sets. Only when data combination is properly made, the provision of good services that are based on digital locational multi-source data is possible.

Expansion of the digital media: interactive spatial information services

Digital map production has influenced the contents and means of delivering information services to the public. Geographic information services are being promoted as 'useful' in several fields of the information society, including resource management, retailing, and tourism (Kasvio 1997). There is also an increasing demand for flexible access to digital geographic information within Finnish government and corporations. As maps often form a backbone to an information system, printed maps have been either accompanied or replaced by digital spatial information accessed through several types of digital interfaces (e.g., mobile phones, the Internet, information kiosks). By augmenting or replacing paper versions, the model of map use has changed from static to interactive. This means that geographic attribute data (including spreadsheets, 3D animations, and video) are accessed through a dynamic interface.

Contemporary developments in Finnish mapmaking show an increase in the number and type of digital spatial registers and customised map services. Many municipalities and marketing companies have established their respective map databases on the Internet, with specifically designed search, query, and multimedia functions. New data is now collected directly into digital form (e.g., high-resolution airborne remotely sensed data) and existing analogue data sets are converted into digital data formats. For example, the seventeenth-century geometric maps of Finland were digitised in a shared effort by the Department of History of the University of Jyväskylä and the Center for Scientific Computing (CSC). The result can be accessed through the Internet (*www.csc.fi/maakirjakartat/*). Further, the "Karttapaikka" searchable Internet map database, implemented by the National Land Survey in 1996 (*www.kartta.nls.fi/*), enables a user to explore maps from any region in the country up to the scale of 1:50 000. Finer-scale maps are available upon a prepaid session fee (Niemelä 1998: 92). Digital GI is also distributed in form of digital atlases on compact disks and sold to clients with map-reading software. Digital atlases are also made GPS compatible. Among the first products to appear in the market in 1998 and 1999 for digital navigation were two raster-based road maps (*GT-Suomi*, *CD-Tiekartasto*) and two vector-based route planning systems (*Genimap AT* and *YT*). An Internet-based search engine for environmental literature in the Archipelago Sea Region, using a map interface, has been established recently (Tolvanen 2001).

When access to the Internet through wireless devices comes into mainstream use, data is not only explored in an interactive manner, as with stationary Internet access devices, but the user's location becomes an input variable. Cartographic services that are keyed to this location variable have been dubbed "Location Based Services" (LBS). The key to LBS is then to facilitate the access to selected information contents, appropriate in context (users requirements), location, and time. For example: While the traditional use of city maps is based on *reading* their information, future mobile devices can transfer the same message in many different ways. It is often unnecessary to see the information plotted over a map if the same message could be delivered otherwise, for example, by spelling out: "Just continue walking along this road." Even in these connections, however, the primary function of the automated system is based on digital GI and coordinates, maps, and algorithms concerning their relations.

If LBS systems, such as personal navigation, penetrate into everyday use, future travellers may load their portable communication platforms with map information and, having set their individual content preferences, interact with a four-dimensional data set (geographic dimensions and time) as they move through the physical world. While moving, navigation systems with real-time GPS linkages will then activate the relevant information based on the position of the user and the predefined sites of interest. With the eventual introduction of the third-generation (3G) mobile phones and hand-held computers, all the necessary equipment will be carried along easily (Kalliola 2000a). Working LBS prototypes already exist. Much development is still needed on technical issues (such as data, software, and communication standards), but some of the most essential research concerns the sociological, ethical, and legal issues accompanying LBS systems.

We outline the following model for a traveller's information service of the early twenty-first century. The system envisioned is a wireless navigation and information assistant running on a hand-held computer and linked to a GPS, using third-generation mobile phone networks for GI data transfer (CD-Fig. 3). This concept is based on linking the real-time position of the user with remote dynamic GI databases that contain contextual data on the user's environment. For the system to function, all relevant data sources relating to the same area (ranging from historical maps to accurate satellite imageries) are first made compatible with each other and stored in a distributed computer environment (Krisp 2000; Lähde 2001). Their substance contents can be linked with each other interactively to fit ideally to the actual needs of information, reaching hundreds of years backwards in some areas. Query results can be visualised in a number of ways, including cartographic representations, virtual landscapes, and multimedia solutions. The interface provides access to common mapping queries, such as search, location finding, zoom, pan, and help. In the first example (CD-Fig. 3A), our hypothetical guide shows the position of the user vis-à-vis a three-dimensional visualisation of the landscape from 1690 and 1998 data sources. In the second example (CD-Fig. 3B), the guide shows three visualisations of park management effects in the forest at the user's position (Tahvanainen et al. 2001).

In the light of these trends, the ways that spatially organised geographic information is stored and delivered to the people has expanded during recent years. The traditional cartographic communication model is becoming more dynamic. GI systems that enhance a user's experience in reality are being developed. In these systems, real-time data from sensors are incorporated into maps (Raper 2000) and reality is supplanted by letting a user explore GI-based virtual realities (Rakkolainen et al. 1998). Digital databases have introduced a multifaceted model of cartographic reality, where information is stored both as locational and non-locational data using either vector or raster data structures (formats). Locational data that refers to coordinate information is used in drawing and displaying geographic features, while non-locational information (i.e., attribute data) of the mapped features forms 'the message' on the interface (Robinson et al. 1995: 169–177). As a result, the three basic map attributes of scale, projection, and symbolisation (Monmonier 1996) are being changed and adjusted by the map users when creating their own maps. Maps are also becoming not only abstractions of a physical reality, but spaces that the users can explore. As an example, mapping based on remote sensing may employ image and sound (and eventually smell and touch) recorders with real-time links to the map interface. With such a system of sensors connected to a location-aware mapping system, the 'map' becomes, in actuality, an image (or sensual representation, if other senses are evoked) of the user in the 'mapped' environment (Burnett & Kalliola 2000). Such maps may update in real time and will include over-laid directional and velocity vectors or other data.

Digital maps – reliable maps?

In parallel with the trends of expanding cartographic communication in the digital realm, pressure is increasing for (1) a critical examination of methods for increasing and communicating data quality; (2) an improved understanding of the interactive spatial information exchange model; and (3) ideas on how to address issues of privacy and data ownership. Burnett and Kalliola (2000) argued that the changes we now engender and witness are so unique that they herald a new era in spatial information communication. These changes relate to how our societal changes are generating demand for digital technologies and to science and technological actors that respond with rapid artefact development.

Digital maps, created from GI databases, suffer from the same malaise as printed maps: they may be as inaccurate and misleading as any printed map despite being products of the most recent technology. These problems do not necessarily relate to their digital format as such, but, rather, to our weakness in handling and using digital data and – often – lack of product-related information. Some fundamental principles in mapping, such as geodesy and survey technique, run through all historic cartographic production modes and have remained unchanged despite the rally of spaceborne remote sensing and automatic positioning techniques. Three major causes for inaccuracy and poor quality in digital maps can be addressed. These problems arise with the combination of digital data, the visualisation of geographic data, and the production of digital maps in a market economy.

Firstly, since GI is increasingly stored in digital and geo-referenced formats, data combinations can be created in a very flexible manner, at times creating poor-quality maps. Even though much of the confusion in data properties can be tested, modelled, and documented, there will be increasing heterogeneity and inconsistency between GI datasets. This is due to combining spatial information produced by different disciplines and organisations. Thus, there is a need to assess the nature of spatial information in a broader sense to be able to understand spatial and temporal scales and relations of GI. Much discussion has been involved around metadata (structured information on the content and format of datasets) standards and GI data structures (ISO/TC 211 Geographic Information/Geomatics Metadata). Well-documented and described metadata about GI is essential and should provide the user with relevant knowledge of the data characteristics (such as its processing history) and help in the task of evaluating and combining GI from different sources. Metadata, however, is not necessarily effective enough to overcome the ontological differences of spatial information coming from different sources (Bowker 2000).

Secondly, a variety of cartographic visualisation techniques, such as the use of colors, is directly applicable in the digital realm. Yet, novel solutions are needed to better meet the restrictions and possibilities computer and GSM phone displays and new printing tools bring about (Kraak & Ormeling 1996). To design a map layout requires knowledge of how colour combinations can best be related to the message the map is supposed to deliver (Monmonier 1996; Nurmi 1999). As non-professional map makers (who may be unfamiliar with basic visualisation rules) can now access digital data (e.g., from a digital topographic database purchased from the NLS), there is a risk that map products will perform poorly. On the other hand, when professionals have access to a digital GI database, incorporation of new information and changes to the visual appearance of the map can be tested and implemented efficiently.

Of course, society must accept or reject these changes. It was no surprise that when the visualisation of the Basic Map of the Finnish NLS was changed during the 1990s, much criticism was presented towards accuracy and usability of these maps compared to the previous map versions. The critics focused especially on cartographic visualisation and applicability of the natural landscape features (e.g., topography, soils, forest cover). For example, no longer was it possible to distinguish pine from a spruce forest, one of the most important tree species indicating differences in soils and moisture (Shemeikka 1998; Kallio 1999). As these visualisation changes were made simultaneously with digitalisation, much of the blame was put on these production changes. Digitalisation generally widened cartographic information, however, since no longer are the printed and the digital product the same. In other words, much ancillary information for each Basic Map lies in the digital database and only a selection is visualised on a printed map. These differences between digital and analogue maps are not necessarily clear to map users. Once a single digital product has been criticised, the criticism is misdirected to digitalisation in general.

The third major source of map quality problems is the effect of GI, GI tools, and digital communication modes (Internet, CD) on marketed products. Some alarmingly unsatisfactory digital map products and freeware base maps have been distributed. They have already damaged the 'image' of, or public trust in, digital products in general. If maps contain obvious location, naming, and content errors, like in the case of some Internet map sites, false data get distributed widely. Also, many commercial GIS packages contain example data sets, which may not be meant for any serious use. They are widely used, however, and also silently accepted (Kalliola 2000b). Government mapping institutions have traditionally set the standard for cartographic products. Partly as a cost-recovery method and partly to control the quality of associated products, these institutions charge significant sums of money for digital data. Companies that create new products have access to fewer resources than government agencies and are usually not able to finance purchases of government databases. In addition, these companies are often in a competitive situation, which prioritises rapid development over map quality. This problem is thus a juxtaposition of two broader technology issues set within a digital cartography context: 'data quality versus cost' and 'state versus market-determined standards'. We believe that this quality problem is a part of normal socio-technical artefact development and that the criticism regarding the dubious quality of early-to-market products and the lack of standards is an important part of this evolution.

Conclusions

For present-day scientists, the Finnish cartographic legacy is a windfall as archives burgeon with valuable representations of the country's landscape. These historical maps reveal important changes in the landscape and document the ways land was used and maps were made at different times. We believe that this cartographic tradition is an important guide to the development of new and innovative, but reliable and sustainable, ways of producing and using GI in the coming decades. New data sources and processing methodology continue to test the skills of GI experts and open up interesting new cartographic 'views' on human and natural worlds. Geographic information can now be combined to produce a myriad of user-defined thematic maps. This utility only arises, however, with careful attention to the spatial accuracy and thematic content of the created digital data layers. All use of combined data must be conducted with reference to data individuality and intricacy.

Once digital GI data is combined, new services may be developed quickly, especially when connected to automated locational systems and portable computing devices. The challenge here is to understand the human–computer interaction factors so that larger societal issues of usability, privacy, sustainability, and copyright are accounted for. Finally, issues of data quality must be foremost in the minds of cartographers. Whereas traditionally the requirements of the government dictated standards, now many parties, both public and private, create maps. The speed with which digital geographic data can be collected, processed, and distributed to the public has increased enormously. Changes both in cartographic design and conventions of distribution (including standards of acceptable accuracy for different levels of digital map data) will come about. Cartographers and geographers will play an active role in these technical and social changes, helping to guide the future of maps in Finland.

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