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American Cartography 2011: Benchmarks and Projections

The National Report of the United States of America to the International Cartographic Association

Guest Editor: Rob Edsall

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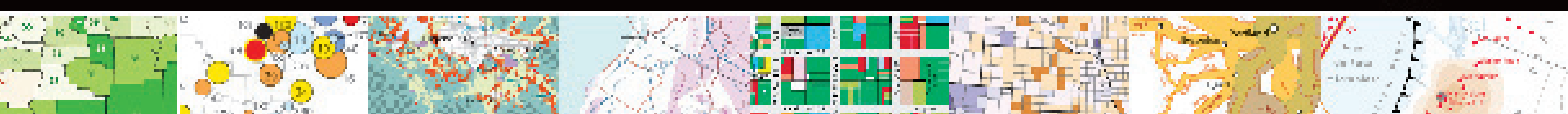

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American Cartography 2011: Benchmarks and Projections

An Editorial Preface to the National Report of the United States to the International Cartographic Association

Robert Edsall, Guest Editor
US National Report

Introduction

The age of ubiquitous cartography has arrived. Maps, whether defined narrowly or broadly, are a part of our technology-filled lives more than ever before; each new day surely sets an all-time record for the number of maps produced, manipulated, and used in the world. And those maps are changing in ways that are obvious today but impossible to have imagined a few short years ago. Interactive and dynamic maps are no longer novel conveniences but de rigueur necessities for an amazingly diverse collection of uses and users: a traveler planning an international voyage expects that a web search for a hotel to be map-driven; a smartphone manufacturer bases advertising on the quality, detail, and usefulness of its maps; a teenager moves through a virtual game world with a meticulously designed, multiple-level-of-detail map; a newspaper includes interactive graphics that allow a reader to visualize and analyze developing stories; a worldwide software corporation constantly improves its interactive maps to keep up with competing products; a cyclist shares knowledge of potholes and angry dogs along her route with others via wiki-based mapping applications; a government agency responds to user (and inter-agency) demand for user-friendly geo-interfaces to its spatial data; an emergency manager coordinates responses to a national security threat with an interactive map as the framework; a community organizer for a small non-profit shares experiences of individuals from his community through a grassroots public mapping project; an aid worker directs resources according to a up-to-the-minute map that shows geo-referenced tweets, photos, and messages from individuals directly affected by an earthquake or tsunami – a map that can quite literally save lives. Cartography continues its renaissance – we can answer the question "hasn't the world already been mapped?" with the astonishing answer "there has never been so much to map."

As exciting as these changes and potentials are, cartography research and development groups in government, industry, and academia are challenged to remain nimble enough to appear progressive rather than reactionary, to remain essential rather than extraneous. We must counter the misperception that these ubiquitous maps "design themselves," and that the decades of vital cartographic research of the past – and future – are no longer important in the maps' usefulness and potency. Indeed, many long-established cartographic principles of simplicity and efficiency in graphic communication are more evident – and found in more contexts – than ever. The desire that your message "go viral"

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in a social media context, for example, requires clarity, succinctness, and easily consumed visual displays, such as in the increasingly popular "infographics" that keep the message short, direct, and – importantly – memorable. Our research now must expand from visual communication to wise and responsive advances in form and function through novel modes of representation, interaction, abstraction and selection, evaluation, and visualization.

Every four years since 1984, this journal has published the National Report of the United States to the International Cartographic Association (ICA). Our reports have, over the years, served as important benchmarks for the state of the art in American cartography, showcasing seminal work through the years in directions such as "computer cartography," atlas mapping, psychometric experiments in map reading, generalization, analytical cartography, cartographic communication and exploration, data modeling, geographic visualization, mobile mapping, and a wide variety of important products and applications of cartography from industry, government, and academia. I'm honored to have been asked to edit the 2011 Report, which coincides with the 15th General Assembly of the ICA in Paris.

Since 1984, our reports have coincided with the ICA General Assemblies, which are major international events in world cities, complete with exciting opening ceremonies, peer-reviewed technical paper sessions in applied and theoretical cartography, major disciplinary keynote addresses, lively discussions and debates that advance our field, and colorful showcases of national culture and international accomplishments in cartography. In many ways the assemblies are similar to world's fairs or Olympic games: celebrations of cooperation, innovation, pride, and achievement. In selecting authors and papers for this report, I had such a celebration in mind; while we can take great pride in our national accomplishments in research and applications in cartography, we do so with the knowledge that many trends reported here are global and international in scale and importance, and that further advancement of the field is done primarily through international partnership and cross-pollination, which closely aligns with the mission of the ICA. The major purpose of this Report is to represent the broad spectrum of current research in the United States on areas of relevance to the ICA, and to highlight the original, significant, and energetic efforts that are advancing cartography and responding to, and in many senses, creating the changes in the way maps and geographic information are being created, disseminated, and used in today's society.

In the call for contributions to the Report, I followed the lead of guest editors before me and asked for a variety of types of papers. First, authors could submit longer, fully peer-reviewed papers that either review the state of the art of an important branch of American cartography or present novel research to solve a specific problem in cartography (or both). Second, I requested research "notes" that gave medium-length summaries of accomplishments or perspectives on dynamics in cartography from various points of view; the editors reviewed for content and clarity by the editors. Finally, I invited reports of activities of various institutions and societies that present a cross-section of activities, personalities, and places that shape American cartography at the beginning of the second decade of the 21st century.

While I did not plan in advance for specific themes to be highlighted in the submissions, several themes quickly became apparent in the submissions. The first and foremost of these is the focus on the changing roles of users of the maps. Ming-Tsang Tsou, in his review of the state of web cartography, sees the "rise of user-centered design" as a major trend in all of mapping, much of which, of course, is happening on and between computers via the Internet. He sees the cartographer's role as changing from a communicator of an idea to a provider of the means for displaying ideas, tracing the remarkable worldwide trend of user-generated content and speculating about its future. User-generated content is also a primary theme in Fritz Kessler's contribution about the implications of so-called "volunteered geographic information" (VGI) and "neogeography." He finds open questions in neogeography, including important research imperatives to determine if VGI is more or less reliable than more top-down data collection approaches that may be more controlled but far more sparse in space and time. He contextualizes such problems reflexively through his own experiences and analysis of VGI in the context of recreational bicycling.

Kessler's paper also demonstrates the symbiotic relationship between modern maps and everyday activities. To today's young people, digital maps are so entwined in their everyday experience that, according to Francis Harvey and Jennifer Kotting, new approaches should be adopted to educate these "digital natives" in modern cartography. They report on the development of a new course designed for college students for whom the use of technology in general, and of digital interactive dynamic maps in particular, is so commonplace as to be taken for granted. Using contemporary educational literature and practice, they adapt pedagogical models responsive to these new learners into a new cartography/GIScience course, and report on their successes and goals. In his paper on the parallels between games and cartography, Ola Alqvist notes that maps have had historical roles in seemingly banal recreational activities, but that these activities, now technologically advanced networked digital games, could now show cartography paths toward the future in visual and computational design.

Tsou's user-centered design focus is echoed in the paper by Vince Smith and Jon Thies, from Intergraph, who have first-hand knowledge of the changing demands of customers and map users. American software designers are responding to the ever-expanding expectations of map users, once satisfied to use paper maps created by others, but who are now expecting not only seamless and user-friendly platforms to display data but also the provision of that current (and "raw") geo-data. Is such a shift from completed cartographic products to modular, do-it-yourself mapping environments leading us to a diminished role for artisanal cartographers? Howard Veregin, who recently worked for Rand McNally, gives his perspective on the new role of cartography in the web-enabled digital mapping age. He argues that "geoenabled" cartography, which relies on GIS and the rules and procedures that characterize it, can be seen as a liberation for cartography, long mired in tedious "silos" of map production: the efficient creation and sharing of maps – as well as the data and procedures used to make the maps – will in fact foster communication and evolution in cartographic design. For present users, the map is not enough – both papers argue that tech-savvy users of maps now wish do delve deeper: into analysis, into problems, and into the data itself.

Geoenabled cartography, introduced by Veregin, is well illustrated by Doug Vandegraft's report on activities at the US Fish and Wildlife Service, where a team of cartographers was responsible not for the creation of a set of maps, but rather the construction and provision of a comprehensive database of geographic information regarding the FWS's property and other related cadastral data. Additionally, the team has made the data available though an interactive web interface. The US Census Bureau shares a commitment to user-centered access to the wealth of data collected for the 2010 decennial US Census; Constance Beard and her colleagues provide us with a tour of the activities of the cartographic branch of the census, illustrating the increased efficiency of geoenabled mapping through the development of databases and software that enable rapid and automated map creation for both census operations and outreach and communication.

The US government's longstanding commitment to providing comprehensive and free geo-data is a clear source of national pride; in particular, a number of papers in the issue describe important research in the creation of the National Map. This project, a cornerstone of the US Geological Survey and the Department of the Interior, provides digital topographic information for use in base maps, scientific analysis, recreation, and other uses. It is designed to update and digitize the familiar "topo sheets" that display elevation data as well as settlement, roads, and hydrography. Lynn Usery provides an overview of the research arm of the USGS' cartography team at the Center for Excellence in Geospatial Information Systems, and discusses the initiatives underway to provide access to the National Map data using user-centered design. Kari Craun and her colleagues showcase the modernization and archiving of the topographic data in the National Map and the creation of a new online version of the National Atlas of the US. Finally, Barbara Buttenfield, Lawrence Stanislawski, and Cynthia Brewer present cutting-edge developments in the landscape-specific methods of generalization of the National Map's hydrography dataset, the detail of which depends on the display scale.

These papers are interspersed in the issue with brief reports from several universities that have proud and ongoing cartographic traditions (Kansas, Penn State, Minnesota, South Carolina, and Ohio State) and activity reports from societies that promote the discipline and enable exchanges of ideas in the United States (CaGIS, NACIS).

Clearly, this is an exciting time for cartography, both here in the United States and worldwide. If you are an international reader, those of us involved in the Report would be pleased to welcome you to the US to share your work and find out more about ours, possibly at the next General Assembly meeting in 2015, but definitely at meetings such as AutoCarto, GIScience, and NACIS, or in individual or collective partnerships with us. This has been an exciting project for me, as I have been exposed to large parts of the spectrum of current cartographic research in the US. It has been a pleasure to work with the dedicated contributors, and I am deeply indebted to the panel of reviewers who provided tremendous feedback to me and to the authors in the process of assembling this report. I am also tremendously grateful to the USNC, chaired by E. Lynn Usery, the managing editor of the journal, Scott Freundschuh, the figures editor, Thomas Hodler, and the editor-in-chief, Michael Leitner, for their support and advice from the beginning. I hope this Report similarly inspires, provokes, and invites you to pursue creative and collaborative work in our dynamic discipline.

About the Author: *Rob Edsall* has been an assistant professor of GIS and cartography at the University of Minnesota since 2008, and will begin an appointment as an associate professor at Carthage College in Kenosha, Wisconsin in Fall 2011. He teaches cartography, GIS, and research methods, and is involved in research in geovisual analytics, multi-modal interface design, and GIScience-society interaction.

Revisiting Web Cartography in the United States: the Rise of User-Centered Design

Ming-Hsiang Tsou

Abstract This paper reviews the recent development of web cartography based on Plewe's 2007 short paper in the U.S. National Report to the ICA, titled *Web Cartography in the United States*. By identifying major changes and recent research trends in web cartography, this paper provides an overview about what the web means to cartography, and suggests two major research directions for web cartography in the future: 1) the rise of user-centered design, including design of user interfaces, dynamic map content and mapping functions; 2) the release of the power of map-making to the public and amateur cartographers. I also present web cartography concepts in this paper to challenge the traditional research agenda in cartography.

Keywords: web cartography, user-centered design, neocartographer

Introduction
Redefining Web Cartography

The hybrid or the meeting of two media is a moment of truth and revelation from which new form is born... the moment of the meeting of media is a moment of freedom and release from the ordinary trance and numbness imposed by them on our senses (McLuhan 1964, p. 80). The web is the new medium of maps, changing cartographic representation from paper and desktop GIS to distributed, user-centered, mobile, and real-time geospatial information services. Web cartography is a new frontier in cartographic research transforming the design principles of map-making and the scope of map use.

Following the argument made by Plewe's 2007 paper, the recent development of web cartography research "has not been nearly as dynamic as the commercial sector" (Plewe 2007, p. 135). In the United States, only a few cartographers focus on web mapping research topics, such as web mapping protocols and standards, map application programming interfaces (APIs), mashups, performance and usability, and user-generated map contents. Many cartographers view web mapping as a technical solution rather than an academic research topic. Web cartography plays a less significant role in academics compared to other topics such as visualization, generalization, and thematic map design. For example, the ten major keywords identified by the International Cartographic Association (ICA) for the 2005 ICA brainstorming sessions did not highlight any major web mapping research topics. There is only a tiny paragraph that mentions web mapping in the ICA report (Virrantaus et al. 2009).

Most cartographers would agree that web maps are becoming more and more important in our daily lives and scientific research. The disconnect between the relatively few academic research projects in web cartography and the great popularity of web maps may be explained by the slowness of academia and the rapid changes of web technology. Web cartography has also yet to be defined in the context of "transformative" research, which "involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice

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or leads to the creation of a new paradigm or field of science, engineering, or education." (NSF 2007). Here, I propose to elevate and redefine web cartography in order to highlight its potential for transformative research.

Peterson (1997) identified two important categories of web cartography research: Internet map use (such as map types, various users, and the numbers of maps created) and Internet map-making (including web graphic design, file format, printing, map scale, and maps on demand). "The Internet has made possible both new forms of maps and different ways of using them and, perhaps, has created a new category of map user" (Peterson 1997, p.9). Crampton (1999) focused on user defined mapping, and defined online mapping as "the suite of tools, methods, and approaches to using, producing, and analyzing maps via the Internet, especially the World Wide Web, characterized by distributed, private, on demand, and user defined mapping." (p. 292). Both Crampton and Peterson highlighted the important role of map users in web cartography. Peterson's description emphasized the emergence of new web-based users who are quite different from traditional map users. Crampton further described the new characteristics of web map users who are granted more power and control in web mapping.

In the early development of web cartography, many researchers used various terms to describe similar concepts, such as online mapping (Crampton 1999), Internet mapping (Tsou 2003), web mapping (Haklay et al. 2008), and cybercartography (Taylor 2005). Kraak and Brown's edited book Web Cartography (2001) benchmarked web cartography research at that time. Peterson's two books, Maps and the Internet (2003) and International Perspectives on Maps and the Internet (2008) cover key research in web mapping, including user-centered design (Tsou and Curran 2008), web cartographic theories (Monmonier 2008), cartographic education (Giordano and Wisniewski 2008), and map usability and evaluation (Wachowicz et al. 2008).

This article redefines web cartography as *the study of cartographic representation using the web as the medium, with an emphasis on user-centered design (including user interfaces, dynamic map contents, and mapping functions), user-generated content, and ubiquitous access*. This new definition emphasizes two important research directions for web cartography:

1. The rise in importance of user-centered design (UCD), including the designs of user interfaces, dynamic map content and mapping functions.
2. Releasing the power of map-making to the public and amateur cartographers.

For this definition, the "web" refers to the connected Internet and its broader network-based applications. The meaning of web in this paper is different from the technical definition of the World Wide Web, which is built upon the Hypertext Transfer Protocol (HTTP). The study of web cartography should not be limited to web browser applications only. For example, Google Earth and NASA World Wind can be used to create cartographic representations in the form of digital globe without web browsers. The following sections will start with an overview of web technology development and then discuss the two research trends in web cartography by highlighting related cartographic research projects in the U.S. and their contributors.

An Evolution in Web Mapping Technology, a Revolution in Web Map Design

Plewe (2007) identified four 'generations' of web mapping technologies. The first was based on HTML and Common Gateway Interfaces (CGI). The second was developed by applets and component-oriented web tools (Peng and Tsou 2003). The third generation included mashups, asynchronous JavaScript and XML (AJAX), and API-enabled mapping applications. The fourth generation came with the invention of Google Earth (and other digital globes, such as NASA World Wind and Microsoft Virtual Earth), which created an immersive mapping environment for users. From a technological progress perspective, these changes in computer science and web technology were an evolutionary process rather than a technology revolution. The evolution of web mapping technology continues today. The fifth generation of web maps is built on cloud computing, rich internet applications (RIA), and crowdsourcing. The following is a short summary of the three key technologies for the new generation of web maps.

Cloud computing: delivers applications, software, and infrastructures as services to many users from distributed data centers over the Internet (Buyya et al. 2009). Users can directly use web-based software (such as Google Docs, Gmails, and ESRI ArcGIS Explorer online), instead of downloading and installing desktop software on their local computers. Programmers and application developers can also use cloud computing to create virtual servers and on-line computing platforms (such as Amazon's EC2 platform and FGDC's Geospatial Platform) for their web applications rather than maintaining expensive local web servers and hardware equipments for their projects .

Rich internet applications: refer to a set of web programming methods for producing interactive asynchronous web applications (Farrell and Nezlek 2007). RIA can provide very user-friendly, high performance, and responsive web applications with powerful user interface gadgets and tools (Kay 2009). Some popular RIA methods include Adobe FLEX, Microsoft Silverlight, and Java Scripts.

Crowdsourcing: is a new approach for generating data or reporting information by amateurs, volunteers, hobbyists, or part-timers (Howe 2006). A large group of people without professional cartographic training can create and share their own maps and geospatial data online. Volunteers can contribute their local knowledge and efforts to collect mapping information by using GPS, mobile sensors, and web mapping tools, such as OpenStreetMap project (Goodchild 2007; Haklay and Weber 2008).

The evolution of web mapping technologies could lead to a revolution of web map designs. In this article, web map designs refer to the integrated design plans for creating effective map user interfaces with dynamic map contents, and mapping functions. Powerful web platforms (RIA and cloud computing) can lead to the creation of innovative map user interfaces. Diversified web user tasks (such as navigation, location-based services, housing and renting, etc.) require unique designs of dynamic map contents (map displays) and mapping functions in order to satisfy different user needs.

Similar to the impacts of Web 2.0 to our society (Batty et al. 2010), web maps have changed the context of cartographic representation; from traditional thematic mapping on paper or desktop computers to user-centered map applications on various mobile devices, virtual globes, and web browsers. Several cartographic studies have highlighted this new design direction with the creation of neologisms, such as maps 2.0 (Crampton 2009), GIS/2 (Miller 2006), neogeography (Turner 2006), and neocartographers (Lui and Palen 2010). These commentaries illustrate the needs for creation of new web map designs to cope with these dynamic changes.

The first wave of the web map design revolution may be observed in 2005, when Google released its two popular mapping services, Google Maps and Google Earth. Miller describes this revolution as new form of GIS, called "GIS/2", enabling the creation of more dynamic and "socially mutable" (changeable and sometime contradictory) geospatial information (Miller 2006), accommodating "an equitable representation of diverse views, preserving contradiction, inconsistencies, and disputes against premature resolution." (p. 196). A related term, "Maps 2.0," was used by Crampton to describe "the explosion of new spatial media on the web, the means of production of knowledge are in the hands of the public rather than accredited and trained professionals" (p. 92). Harris and Hazen (2006) both caution and celebrate that the use of crowdsourced geospatial data by the public in mapmaking may cause counter-mapping and counter-knowledge. One key factor that led to the first wave of web map design revolution was the dramatic improvement in web mapping performance with the adoption of tile-based mapping engines and AJAX technologies (Tsou 2005)., which improve client/server communication response time significantly and generate multi-scale map graphics rapidly. Tile-based mapping engines also improve the performance of web maps by storing a set of pyramidal image layers at different map scales inside web map servers. AJAX and image tiling have existed for a while, but the combination of the two technologies was not seen until 2005. Google maps and Maps.search.ch and are two early examples of web GIS applications using both AJAX and image tiling techniques (Tsou 2005).

The second wave of the web map design revolution is the development of mobile mapping on smart phones, tablet PCs, and GPS devices recently. The popularity of smart phones (such as iPhones, Androids, and Blackberrys) and mobile devices (iPads and tablet PCs) is forcing new map user interface designs (using fingers or voice commands as input devices), new mapping functions (tracking friends, navigation, comparing housing values, etc.) and new map content (GPS tracks, messages in social networks, volunteered geographic information, etc.). Apple's iPad devices have several good examples of new web map designs showing innovative web map user interfaces with unique mapping functions and useful map content. The portability, friendly multi-touch screen inputs, and the large screen display, along with its internal locational awareness, make Apple's iPads, and similar tablet devices, a perfect match for innovative web map design. Hundreds of web mapping apps have already been developed for iPads, such as Urbanspoon, GPS HD by MotionX, UpNext 3D Cities, ESRI ArcGIS for iPad, Zilliow.com, etc. This second wave of the web map design revolution was enabled by both portable hardware design and fast software distribution frameworks (such as Apple's App Store and Android's Market Place). Users can easily download and install mapping software directly to mobile phones without worrying about complicated software license settings or installation procedures. Most mobile software development kits (Apple's iOS and Google's Android) are open and free for software developers to download. Open-style software development environments and online application stores have created a great opportunity for small GIS companies and individuals to develop and share innovative web mapping services.

The Rise of User-centered Map Design

Different from traditional cartography, mobile mapping and interactive web maps place more emphasis on the locations of users and user-centered tasks (such as shopping, navigating, and searching), rather than the visualization of spatial phenomena (such as population density, crime rates, and land use) and thematic map design (such as the arrangement of map elements, symbology, and typology). This trend shifts the research focus of web cartography from geovisualization (emphasizing visual analysis functions and thematic maps) to user-centered design (UCD), including the designs of user interfaces, dynamic map contents and mapping functions. UCD in web cartography emphasizes the usefulness and practicality of web and mobile maps, serving the needs of individual users and customers.

Although the concept of user-centered design has been introduced in GIS and cartography before (Medyckyj-Scott and Hearnshaw 1993; Tsou and Buttenfield 1998), most early desktop-based GIS applications did not emphasize UCD. Traditional GIS project users were mostly decision makers and GIS technicians who are familiar with GIS and cartography. On the other hand, web mapping service users are more diverse and most of them do not have any cartographic knowledge or GIS experiences. Therefore, UCD becomes more important and essential for web map users and web mapping applications.

Web cartographers can design effective and intuitive cartographic representation by focusing on the creation of user interfaces, mapping functions, and dynamic map content. Tsou and Curran (2008) introduced a five stage UCD framework (Garrett 2002) for the designs of web mapping services and evaluation processes. The five stages (strategy, scope, structure, skeleton, and surface) can be split into two design tasks: map content design and mapping function design. The adoption of UCD approaches will improve the quality of web mapping services and generate more useful information services.

UCD is essential for many web mapping projects and applications, including the U.S. National Map. The early development of the National Map Viewer was not very successful due to the unfriendly user interfaces, complicated map content, and slow performance. The 2007 report by the U.S. National Research Council (NRC), *A*

Research Agenda for Geographic Information Science at the United States Geological Survey, recommended UCD as a priority research topic within the area of information access and dissemination in the development the National Map web services (NRC 2007). The NRC report facilitated the development of several web mapping tools and technologies in the new National Map 2.0 prototype, such as GeoPDF and ScaleMaster (Usery 2010). These new technologies have improved the user interface of the National Map Viewer significantly. The National Map uses GeoPDF for its online map publication and download format. GeoPDF is an extension of Portable Document Format (PDF) with a highly portable and compact format, and can be easily transferred, downloaded, and printed (USGS 2010). GeoPDF provides a convenient way for the public to download and view topographic maps without installing GIS software locally. ScaleMaster is another major UCD research tool for the improvement of the National Map; it provides support for multi-scale map design and generalization processes with different themes (such as topographic maps, zoning maps, soil maps, and population density maps) and different scales on computer screens based on different user needs (Brewer et al. 2007).

Releasing the Power of Map-making to the Public and Neocartographers

Creating traditional maps (paper maps or GIS maps) is very expensive, involving costly printing equipment and GIS software. Web mapping tools have reduced the cost of map-making significantly. Both professional and amateur mapmakers can easily use or combine free online mapping services and access high quality online base maps (road maps, aerial photos, or topographic maps). The power of map-making is no longer controlled by professional cartographers or GIS experts. With the development of free and open source software (FOSS) (Tsou and Smith 2011) and free web mapping APIs, "FOSS cartography" and mashup maps have become important componenents in web cartography (Crampton 2009). Mashups are web applications that merge distributed data sources and separated application programming interfaces (APIs) into one integrated client-side interface (Benslimane et al. 2008). Two exemplar free and open source cartographic research projects in the U.S. are:

- web-based epidemiological atlases that utilize PostGIS (a database engine) and GeoServer (a web map engine) (MacEachren et al. 2008),
- demonstrations of interoperability and high visual quality with various web GIS datasets using MapServer (a web map engine), PostgreSQL (database tools), PostGIS extension (database links), and the libxslt XSLT processor (a document parser) (Yao and Zou 2008).

The freedom of web map-making enables amateur cartographers to create their own maps and easily distribute them. They embrace new web mapping tools and free mapping APIs to publish and share their do-it-yourself maps with the whole world. Lui and Palen (2010) used several mashup examples in disaster responses to demonstrate the powerful impacts made by "neocartographers", a new term describing amateur cartographers without formal map design training. Neocartographers are able to create various mashup maps, with "frequently updated data from multiple sources, allow[ing] us to see microbehavior" – in this case, user responses to social network messages by micro-blogging services – "spatio-temporally"(Lui and Palen 2010, p. 70). The emergence of amateur cartographers and free web mapping tools facilitates many do-it-yourself web maps with user-generated contents. One major challenge is how to improve the credibility and how to reduce the uncertainty in these user-generated contents and maps. Cartographers need to develop intelligent information-ranking algorithms and strategies for processing user-generated contents and to filter out inaccurate geospatial data in web mapping services.

The ubiquitous display of maps on various mobile devices is another key factor enabling the freedom of map-making. Developers no longer limit themselves using traditional desktop computer screens or printout maps for map outputs and display. Mobile devices provide flexible and portable map display/output options for web mapping services. It is important to understand the advantages and disadvantages of mobile display in different web mapping services and associated visual design principles. Dillemuth et al. (2007) examined design principles for various map scales and map extents on mobile devices for navigation systems. Gartner et al. (2007) suggested a few research topics in ubiquitous cartography, including 4D (space-time) representation, adaptive representation, real-time navigation, and locational privacy concerns (Gartner et al. 2007). Gartner further described how mobile map users can become part of the map as an avatar positioned in real time using GPS (or RFID, Wi-Fi), and how the mobile map can be dynamically changed or mirror the real geographic place in which the user is situated.

Discussion

Re-inventing the Design Principles of Web Maps for the Renaissance of Cartography

In the last decade, major advancements in web mapping technologies have been advanced by the information technology (IT) industry, rather than by cartographers or other associated academic researchers (Plewe 2007; Haklay et al. 2008). Today, the new medium (the web), the new tools (mobile devices), and the new participants (new map makers and new map users) provide a great opportunity for academic researchers to re-invent the design principles of web maps, including user interface design, dynamic web content, and new mapping functions. These new design principles and strategies will transform the study of cartography into an important scientific and technological discipline with the emphasis of information representation, map communication, and computing functions. Some preliminary ideas for the re-invented design principles of web maps are suggested in the following:

User interface design: voice-activated zoom-in, zoom-out mapping commands, video-interpreting gesture mapping commands, and motion-sensor-based mapping input.

Dynamic map content: augmented reality for web maps, dynamic linkages between movies, pictures, and texts with user generated contents, and time-sensitive map display.

New mapping functions: In-door shopping and navigation tasks, location-based social networking, and presenting the credibility of volunteered geography information.

To enable this renaissance in cartography, this article suggests that the transformative research agenda of web cartography should focus more on user-centered design, user generated content, and ubiquitous access from mobile devices. The ultimate goals of developing innovative web mapping applications and research are to improve our quality of life, resolve human conflicts, and facilitate sustainable development of our society. Ideally, cartographers should be a part of these projects, partnering with computer scientists, sociologists, activists, psychologists, and IT engineers, who will all be transformed to "spatial information designers" or "geospatial information architects" to create innovative web map applications. These innovations in cartography will help us to create a more collaborative, humanistic, and sustainable society.

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REFERENCES

Batty, M., A. Hudson-Smith, R. Milton and A. Crooks. 2010. Map mashups, Web 2.0, and GIS Revolution. *Annals of GIS* 16: 1-13.

Benslimane, D., S. Dustdar and A. Sheth. 2008. Service Mashups: The New Generation of Web Applications. *IEEE Internet Computing* 12 (5): 13-15.

Brewer, C.A., B.P. Buttenfield, C. Frye and J. Acosta. 2007. Scalemaster: Multi-Scale Map-making from Multiple Database Resolutions and for Multiple Map Purposes. In: *Proceedings, 23rd International Cartographic Conference* (ICC2007), Moscow, Russia, August 2007. Online: http://www.personal.psu.edu/cab38/ScaleMaster/ (accessed 23 September 23

2010).

Buyya, R., S. Pandey and C. Vecchiola. 2009. Cloudbus Toolkit for Market-Oriented Cloud Computing. In M.G. Jaatun, G. Zhao and C. Rong (eds.), *CloudCom 2009, LNCS 5931*, Berlin Heidelberg: Springer-Verlag. pp. 24–44.

Crampton, J. W. 1999. Chapter 27: Online Mapping: Theoretical Context and Practical Applications. In: W. Cartwright, M.P. Peterson and G. Gartner (ed.), *Multimedia Cartography*. Berlin: Springer. pp. 291-304.

Crampton, J. W. (2009). Cartography: maps 2.0. *Progress in Human Geography* 33(1): 91-100.

Dillemuth, J., K. Goldsberry and K.C. Clarke. 2007. Choosing the scale and extent of maps for navigation with mobile computing systems. *Journal of Locational Based Services* 1(1): 46-61.

Farrell, J. and G.S. Nezlek. 2007, Rich Internet Applications The Next Stage of Application Development. In: *29th International Conference on Information Technology Interfaces*, Cavtat, Croatia. pp 413 – 418.

Garrett, J. J. 2002. *The Elements of User Experiences: User-Centered Design for the Web*. New York: American Institute of Graphic Arts.

Gartner, G., D.A. Bennett and T. Morita. 2007. Towards Ubiquitous Cartography. *Cartography and Geographic Information Science* 34(4): 247-257.

Giordano, A. and L. Wisniewski, L. 2008. Teaching Cartography on the Web with a Multimedia GIS: A New Solution. In M.P. Peterson (ed.), *International Perspectives on Maps and the Internet*. Berlin: Springer., pp. 219 – 238.

Goodchild, M., 2007. Citizens as sensors: the world of volunteered geography. *GeoJournal* 69: 211-221.

Haklay M.M. and P. Weber. 2008. OpenStreetMap: user-generated street maps. *IEEE Pervasive Computing* 7(4), 12-18.

Haklay, M., A. Singleton and C. Parker. 2008. Web Mapping 2.0: The Neogeography of the GeoWeb. *Geography Compass* 2(6): 2011–2039.

Harris, L. M. and H.D. Hazen. 2006. Power of maps: (counter) mapping for conservation. *ACME* 4: 99-130.

Howe, J. 2006. The rise of crowdsourcing. *Wired Magazine* 14 (6): 161-165.

Kay, R. 2009. Rich Internet Applications. *Computerworld* 43: 34-34.

Kraak, M.J. and A. Brown (eds.). 2001. *Web Cartography: Developments and Prospects*. London: Talyor and Francis.

Lui, S.B. and L. Palen. 2010. The New Cartographers: Crisis Map Mashups and the Emergence of Neogeographic Practice. *Cartography and Geographic Information Science* 37(1): 69-90.

MacEachren, A. M., S. Crawford, M. Akella and G. Lengerich. 2008. Design and Implementation of a Model, Web-based, GIS-Enabled Cancer Atlas. *The Cartographic Journal* 45(4): 246-260.

McLuhan, M. 1964. *Understanding Media: the Extensions of Man*. New York: McGraw-Hill.

Medyckyj-Scott, D. and H.M. Hearnshaw (eds.). 1993. *Human Factors in Geographical Information Systems*. London: Belhaven Press.

Miller, C.C. 2006. A Beast in the Field: The Google Maps Mashup as GIS/2. *Cartographica* 41(3): 187-199.

Monmonier, M. 2008. Web Cartography and Dissemination of Cartographic Information about Coastal Inundation and Sea Level Rise. In M.P. Peterson (ed.), *International Perspectives on Maps and the Internet*. Berlin: Springer., pp. 49- 71.

National Research Council (NRC). 2007. *A Research Agenda for Geographic Information Science at the United States Geological Survey*. Washington, DC: National Academies Press.

National Science Foundation (NSF). 2007. *Definition of Transformative Research*. Online: http://www.nsf.gov/about/transformative_research/definition.jsp (accessed 24 February 2011).

Peng, Z.R. and M.H. Tsou. 2003. *Internet GIS: Distributed Geographic Information Services for the Internet and Wireless Networks*. New York: John Wiley & Sons.

Peterson, M. P. (ed.). 2003. *Maps and the Internet*. Amsterdam: Elsevier.

Peterson, M. P. (ed.). 2008. *International Perspectives on Maps and the Internet*. Berlin: Springer.

Peterson, M. P. 1997. Cartography and the Internet: Introduction and Research Agenda. *Cartographic Perspectives* 26: 3-12.

Plewe, B. 2007. Web Cartography in the United States. *Cartography and Geographic Information Science* 34(2): 133-136.

Taylor, D.R.F. (ed.). 2005. *Cybercartography: Theory and Practice*, Amsterdam: Elsevier.

Tsou, M. and B.P. Buttenfield. 1998. An Agent-based, Global User Interface for Distributed Geographic Information Services. In: *Proceedings 7th International Symposium on Spatial Data Handling*, Vancouver, British Columbia, July, 1998, pp. 603-612.

Tsou, M.H. 2003. Chapter 14: An Intelligent Software Agent Architecture for Distributed Cartographic Knowledge Bases and Internet Mapping Services. In M.P. Peterson (ed.), *Maps and the Internet*. Oxford: Elsevier Press, pp. 229-243.

Tsou, M.H. 2005. *Recent Development of Internet GIS at GIS@development*. Online: http://www.gisdevelopment.net/technology/gis/techgis_002pf.htm (accessed 24 February 2011).

Tsou, M.H. and J. Smith. 2011. *Free and Open Source Software for GIS education*, White paper, GeoTech Center. Online: http://geoinfo.sdsu.edu/hightech/WhitePaper/tsou_free-GIS-for-educators-whitepaper.pdf (accessed 24 February 2011).

Tsou, M.H. and J.M. Curran. 2008. User-Centered Design Approaches for Web Mapping Applications: A Case Study with USGS Hydrological Data in the United States. In M.P. Peterson (ed.), *International Perspectives on Maps and the Internet*. Berlin: Springer, pp. 301-321.

Turner, A. J. 2006. *Introduction to Neogeography*. Sebastopol, CA: O'Reilly Media Inc.

United States Geological Survey (USGS). 2010. *USGS Store - Map Locator & Downloader About GeoPDF Maps*. Online: http://store.usgs.gov/locator/about_digital_maps.html (accessed 20 September 2010).

Usery, E. L. 2010. *Cyberinfrastructure Components of the National Map*. CyberGIS workshop position paper, February 2-3, Washington D.C. Online: http://www.cigi.illinois.edu/cybergis/participants.php (accessed 20 September 2010).

Virrantaus, K., D. Fairbairn and M.-J. Kraak. 2009. ICA Research Agenda on Cartography and GI Science. *The Cartographic Journal* 46(2): 63-75.

Wachowicz, M., L. Cui, W. L., Vullings, W. and J. Bulens. 2008. The effects of web mapping applications on user satisfaction: an empirical study. In M.P. Peterson (ed.), *International Perspectives on Maps and the Internet*. Berlin: Springer., pp. 397-415.

Yao, X. and L. Zou. 2008. Interoperable Internet Mapping – An Open Source Approach. *Cartography and Geographic Information Science* 35(4): 279-293.

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Volunteered Geographic Information: A Bicycling Enthusiast Perspective

Fritz Kessler

Abstract: Mapping technologies have made considerable strides in recent decades. Global positioning systems (GPS), remote sensing satellites, Web-based mapping services, and geographic information systems (GIS) have facilitated the collection, distribution, analysis, and ultimately interaction with geospatial information. In particular, portable GPS have altered how individuals participate in mapping. Individuals can use GPS to collect tracings of their personal interactions with the environment. These interactions can then be uploaded to one of many available Web-based mapping services. Once uploaded, the geospatial data can be mapped and shared among the broader community of users. Such volunteered geographic information (VGI) exemplifies the conceptualization of an individual collecting, mapping, and sharing personal geographic information. This paper focuses on challenges surrounding VGI. To help place these challenges in a broader context, specialized Web services and GPS technologies developed for the bicycling community will serve as examples of the current status and future prospects of VGI.

Keywords: Volunteered geographic information, neogeography, user-generated content, Web 2.0, global positioning systems, and bicycling

Introduction

The World Wide Web (the Web) has evolved from a static encyclopedic unidirectional warehouse of information to a more dynamic, interactive, and participatory medium. This evolution, referred to as Web 2.0, coincides with refinement of geospatial data exchange standards as well as enabling technologies, particularly GPS, that historically were available only to institutional mapping agencies. These concurrent developments enable users to capture personal geospatial data, upload it to a Web service, and share the resulting information with the broader community. Individuals with no special cartographic training or computer programming skills are actively creating and sharing maps and information. Goodchild (2007) calls such data volunteered geographic information (VGI), and those who participate are involved in the broader practice of neogeography.

This short article aims to accomplish three things. First, I provide a brief background on the VGI phenomenon and discuss several important challenges surrounding it. Second, I contextualize these challenges within technology developments and Web services available to the bicycling community. Third, I offer a perspective on the success of VGI and its future.

Volunteered Geographic Information: Development and Challenges

During the early 1990s, the Web was viewed as a depository of downloadable information accessible through hyperlinks. The idea of 'looking something up on the Web' was fundamental to how users viewed and used the Web. As technology evolved, so did the Web. Speculating about the future of Web mapping, Dangermond (1995) and Krygier

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(1999) suggested that one outcome should be to engage users more explicitly and permit them greater access to data, thus encouraging their participation and collaboration, in general, and in mapping, in particular. Map-based Web services such as MapQuest and Yahoo! Maps (both launched in the mid 1900s) allowed users to interact with the Web, tailoring information content to their individual needs (e.g., obtain driving directions).

As technology continued to evolve, Web services like Google Earth and other virtual worlds permitted individuals to become more involved with the creation, maintenance, and distribution of their own geospatial information. O'Reilly (2005), in coining the term Web 2.0, describes the Web's evolution from a unidirectional depository of information to a growing range of personal interaction opportunities, with Web 2.0 referring to individuals collecting, contributing, and participating. More recently, O'Reilly and Battelle (2009) suggest that Web 2.0 has evolved to a new level where intelligence is being incorporated into Web services (e.g., geotagging). Geotagging adds geographical identification metadata such as a latitude and longitude marker, elevation, or place name to a photograph (e.g., iPhones allow automatic tagging of photographs). The photograph then becomes searchable through a Web service such as Wikimedia Commons allowing individuals to find specific locations.

Web 2.0 and related technologies are the backbone upon which VGI infrastructure exists and helps to create the diversity of VGI users and applications. Since Goodchild (2007) introduced VGI other terms have been proposed. For instance, 'people-centric sensing' (Campbell et al. 2008) and 'personal cartographies' (Lauriault and Wood 2009) reflect user-collected information, neogeography (Turner 2006) focuses on map creation for individual needs, and Goodchild (2009, p. 82) suggests that VGI blurs the distinction between "producer, communicator and consumer of geographic information."

Although VGI is relatively new, Tulloch (2008) reflects that many of the same arguments that faced public participation in GIS (PPGIS) in the 1990s are still applicable to VGI. For instance, debates, relevant to PPGIS, questioning what is public, who owns the information, and how technology alters the role that its members play in societal power struggles are still relevant to VGI. In fact, most of these arguments have yet to be fully addressed in the VGI arena. Elwood (2008) categorizes these debates into three main themes: the technology that makes VGI possible, data collection and dissemination, and a characterization of knowledge production. Here, I use these themes to organize and discuss several ongoing challenges in the VGI field. This discussion will also provide a context for a later explanation of how VGI has been integrated into the bicycling community.

Technologies that Facilitate VGI

Elwood's first theme is the technology operating the hardware, software and Web services that enables VGI activities. Web services like World Wind and OpenstreetMap have fewer expert knowledge demands than other information sharing technologies such as GIS or data clearinghouse database servers. VGI Web services have simplified their usability expectations (e.g., through interface design) so that GIS functionality, particularly creating, posting, and sharing information, is more readily accessible to the public. The ease by which this interaction takes place also suggests that more diverse user communities can engage in VGI.

Aligned with expanding user group composition are the concerns raised by Chambers (2006) who reflects that VGI has elicited questions about the data collection process, its resulting empowerment, and the ultimate use to which volunteered data and information is put. For instance, when someone establishes a free account with a Web service or with any social networking site, there is a tacit contract between the account holder and the Web service: in return for providing a free Web service, the company collects and tracks personal information (e.g., spatial location and shopping habits). Dobson and Fisher (2003) refer to this practice of monitoring users and their activities through technology as geoslavery.

Data Collection and Dissemination

Elwood's second theme deals with the ease by which data collection takes place and the volume of information collected and disseminated under the VGI umbrella. This massive amount of data collection has proceeded in a haphazard fashion. The very nature of personal data is quite different than the more structured data associated with, for example, spatial data infrastructure, and thus no single VGI data model has emerged. Craglia (2007) observes that the spatial data infrastructure concept is designed for expert-to-expert data sharing in a GIS environment. VGI relaxes those restrictions in that Web-based services do not expect a certain level of GIS expertise. That VGI is fundamentally open to a wide range of users and their expertise is the fundamental appeal of VGI.

Another important component of spatial data infrastructure is metadata, which is absent from volunteered information. Critical components of metadata include quality, accuracy, and validity statements. As Flannigan and Metzger (2008) discuss, volunteered information does not have an entity (e.g., government agency) or persons (e.g., professional cartographers) to serve as quality control. Since VGI information is quickly collected and disseminated, the necessary time and effort to provide, for example, quality control is lacking. However, Flannigan and Metzger optimistically suggest that the power of social media and the larger community of users of a Web service may serve as an in situ mediator and discredit or correct erroneous volunteered information.

Characterization of Knowledge

Elwood's third theme focuses on the purposes for which the knowledge gained from VGI is used. On one hand, VGI is associated with adding to existing geographic information, while on the other hand VGI helps to foster the production of new forms of knowledge. OpenStreetMap adds to existing knowledge in instances where, for example, public funds may not be available to pay for mapping an extensive road network. Through OpenStreetMap users contribute their own route information to help build a road network database. Adding to existing spatial data through a piecemeal process through Web services like OpenStreetMap is what Goodchild (2007) refers to as a 'patchwork' method and is a key strength of VGI.

Liu and Palen (2010) discuss how 'crisis mashups' of situationslike natural disasters, disease outbreaks, or social unrest can utilize VGI services to create new forms of knowledge. For instance, a crisis mashup can expedite communication of timely information to the public on rapidly changing situations (e.g., specific evacuation routes due to an uncontrolled wildfire). On the other hand, VGI can spark unintentional outcomes of knowledge production. In many communities Web services (*http://www.familywatchdog.us/*) allow you to enter an address and see a map pinpointing the location of all sex offenders. While this form of knowledge allows neighbors to be kept informed of sex offenders' locations and, for example, keep children at bay, the service may unintentionally spark violent retribution against those sex offenders (Nordheimer 1995).

VGI and the Bicycling Community

Elwood (2008) points out that VGI has opened the possibility for different user communities to engage in collecting and sharing information. One community of users that has not received attention in the cartography literature is bicyclists: Those who ride a bike for recreation, commuting, or fitness. This section explores the unique needs of the bicyclist, and the impetus behind developing bicycling-specific VGI services, and how these services illustrate the three themes reported by Elwood.

Spatial awareness is a vital part of riding a bike. Bicyclists frequently ride in their familiar local environment and are well versed about its spatial arrangement: They know distances and travel times along specific routes, which routes to avoid, and where to go for the best bicycle repairs. Chief among their tasks is planning an efficient route for getting to work or for recreation. Unfortunately, bicyclists often face significant challenges in their planning as most of their travels take place on networks designed for motorized vehicular traffic. They also are keenly aware of routes that have lower traffic volumes, fewer changes in elevation, and smoother road surfaces.

As Priedhorsky, et al. (2007, p. 93) offer, bicyclists have a “strong tradition of sharing information.” Up until recently, that sharing has been made difficult by the lack of technology. Prior to 1984, bicycling recording devices were limited to mechanical odometers that tallied the day’s mileage. In 1984, Avocet introduced the first bicycling computer – the Model 20. Although crude by today’s standards, the Model 20 displayed current speed, trip distance, total distance, and ride time. Mapping a route would not be possible until 2007 when Garmin, the manufacturer of GPS enabled devices, developed the Edge series specifically tailored to the bicyclist. Garmin bicycling GPS devices allow the user to instantaneously receive and view route data on the bicyclist’s speed (current, maximum, and average), distance (current and total), and health (power and cadence output). Edge units also continuously record a rider’s location and display the current position on a base map in real time. The coordinate location and various data are recorded as a .gpx file in GPS exchange format, which is readily interchangeable with various bicycling specific Web services.

From a cartographic standpoint, the Edge units come pre-loaded with road basemaps for the United States. Zooming and panning of the maps are possible during the ride. The built-in map database has various levels of detail (i.e., interstate down to street-level detail). If desired, separate MicroSD cards containing additional street-level map detail of road networks of other countries can be purchased. MicroSD cards of 1:100,000 or 1:24,000 topographic coverage of United States are available for mountain biking. Edge users can also see the elevation profile of their route on screen.

Other devices for recording bicycle route information have also been developed. Eisenman et al. (2009) describe BikeNet, which is a mobile sensing system that records real-time fitness data (e.g., heart rate) and environmental factors (e.g., CO2 levels). BikeNet collects information and stores it, but the information can also be uploaded to a server in real time for later analysis. Priedhorsky et al. (2007) explain how their research has lead to the design of a personalized geowiki for the bicycling community. Its aim is to allow bicyclists to contribute to, access, and edit existing bicycle routes. Some notable features include a wiki map of bicycling routes contributed by the bicycling community, a wiki geodatabase of important landmarks (e.g., a local café or an angry dog), route finding capabilities, and personalized bike-ability rankings (e.g., rating the riding difficulty of each route). Similarly, Reddy et al. (2010) discuss Biketastic. By using smartphones as the platform, the bicyclist is provided with an affordable means to record the route for personal or sharing purposes without having to purchase expensive bike-specific computers/GPS devices (e.g., Garmin’s Edge 705 bundled with U.S. street maps costs $700.00). Lastly, GPS-enabled smartphones can sense information about road roughness and noise levels along the route and be uploaded to database. Once completed, the route and associated data can be visualized on the Biketastic Web service (*http://www.biketastic.com*). Trimble, another supplier of GPS-enabled devices, has developed a GPS smartphone application. Through the use of Trimble’s Adventure Planner (*http://portal.trimbleoutdoors.com*), the GPS coordinates of the route can be uploaded and mapped as well as embed pictures or video of the trip. Interestingly, Adventure Planner also allows the importation of a route collected by a Garmin device. Once the route is uploaded to Adventure Planner, the route can be shared. A significant drawback of the smartphone applications to the bicyclist is that the bicyclist has no ability to safely view the data of the route during the ride.

VGI and Bicycling-Specific Web Services

To explore the degree to which VGI has integrated into the bicycling community, I used a Garmin Edge 705 unit to record various bike rides. The details of these rides were then uploaded to three Web services: Garmin Connect, Bicycling-Trimble Outdoors, and MapMyRide. These Web services will serve as a framework for discussing Elwood’s three VGI themes and provide a context for contemplating VGI’s future.

Garmin Connect (*http://connect.garmin.com*) is a free site that allows Edge owners the opportunity to upload their own GPS route data. Once uploaded, the data can be analyzed and shared

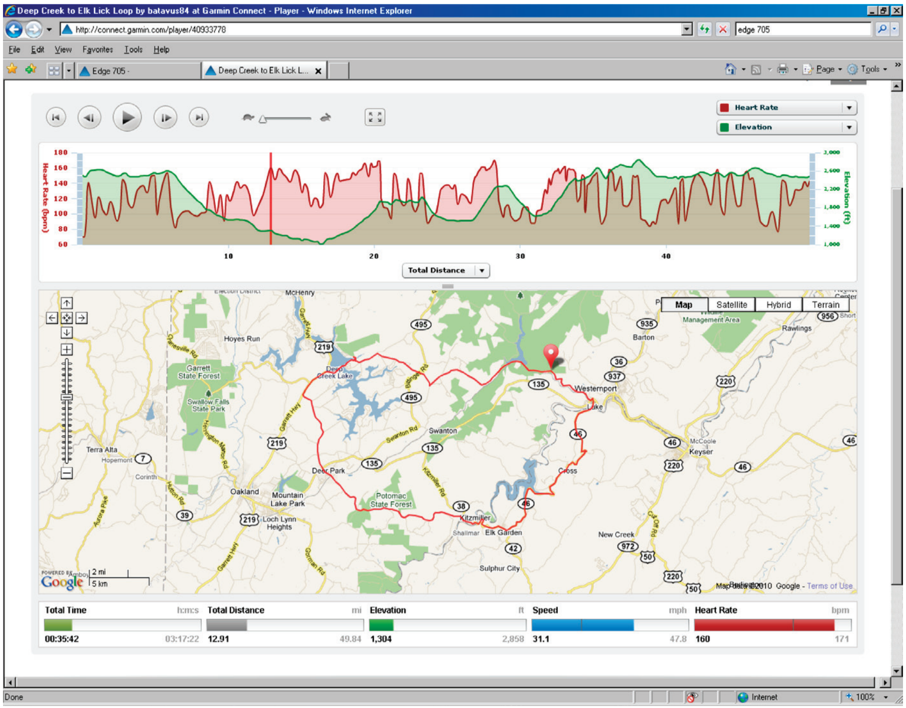

Figure 1. The interactive environment of the Garmin Connect web service. The red line plotted on the map shows the route traveled by the bicyclist. The five graphs below the map indicate various data collected throughout the route. The top graph overlays changes in elevation with heart rate along the mapped route. The animation control buttons allow the red marker on the map to move along the route. As the red marker moves, ride data is updated at the bottom and a red vertical line moves on the top graph showing changes in elevation and heart rate.

through a variety of interactive graphs, charts, and maps. Figure 1 shows ride details pertaining to a route displayed on the Garmin Connect site.

Bicycling Magazine, one of the oldest continuously running bicycling magazines (since 1961), teamed with Trimble Outdoors to bring another VGI Web service to the bicycling community. Unlike Garmin, Trimble does not produce a standalone bicycling specific GPS device, but rather markets a fee-based application that can be downloaded to a mobile phone. The Smartphone application records data and the GPS coordinates during the bicyclist's ride. The route information is then uploaded to the Bicycling-Trimble Outdoors site (*http://bibicycling.trimbleoutdoors.com*). Users register a free account on the Web service after which they can upload any .gpx file (or other GPS file formats).

MapMyRide is another bicycling-focused Website hosted by MapMyFitness, a Denver, Colorado based company that offers Web services, such as MapMyWalk and MapMyRun, to outdoor recreational enthusiasts. Similar to the Garmin Connect and Trimble Outdoors site, MapMyRide offers the bicyclist the ability to post the route for detailed viewing of collected data and analysis of the ride. As with the Garmin Connect and Bicycling-Trimble Outdoors sites, MapMyRide provides a summary of basic route data, such as distance, time, and elevation climbed. All three Web services rely upon Google Map data as cartographic base information. The user has options to display the route in street, satellite, hybrid, terrain, and topo formats.

Technologies that Facilitate VGI

Collectively, these three bicycling Web services illustrate examples of how simplified technology facilitates mass involvement in VGI. For instance, the Garmin GPS device came with a quick start guide that simplified the device set up and instructions on data uploading. Uploading data to these three Web services was easily handled. A free account on each site was created, the unit was plugged into a USB port, and by following the on-screen instructions, the data was uploaded and mapped. The amount of time involved from plugging the unit into the USB port to seeing a map of the data took less than three minutes per site. If a user had to write code, download drivers, or configure/format the data file, these Web services would not be as easy to use and thus not as popular.

Reducing technological hurdles has certainly encouraged users to explore these Web services and utilize the various tools. Figure 2 shows the interface of the Bicycling-Trimble Outdoors Web service which includes a Map Editor tool.

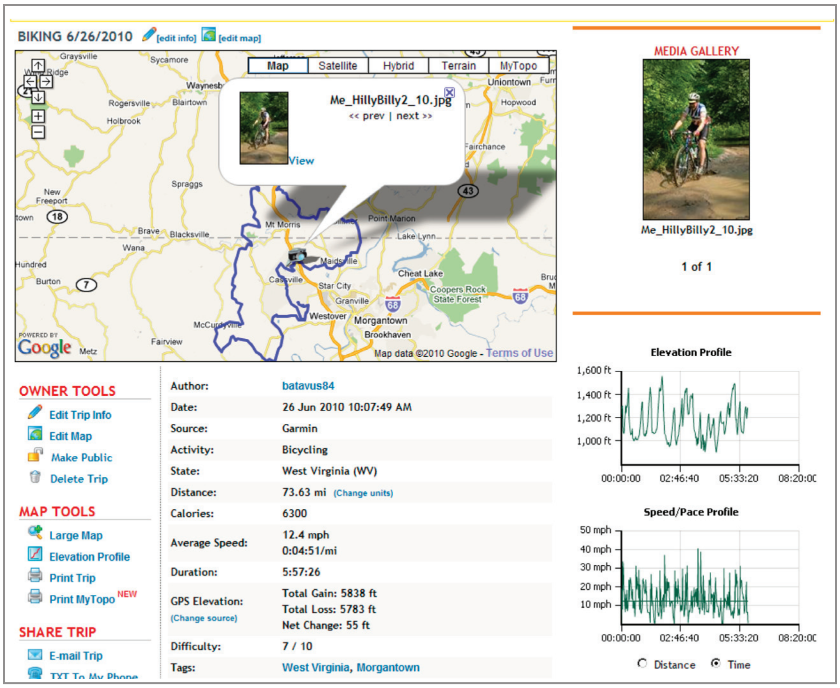

Figure 2. Showing the image viewing function of the Bicycling-Trimble Outdoors bicycling Website.

By using the Map Editor tool, a route can be created, modified, or annotated. For example, a new route can be sketched directly on the map using the freehand, point and click, or follow-roads tools. Distances can also be computed using the measure tool. Even a point of interest (e.g., location of a dangerous dog) can be marked. The Map Editor tool also permits images to be embedded into the map along the route where the picture was taken. Once completed, a small camera icon appears on the route alerting viewers that an image is available for viewing.

MapMyRide packages route information together in ways not offered by the other Web services. Figure 3 illustrates the change in percent grade (-6% to +6%) along the route. By using a color scheme, various changes in grade are highlighted which is very important to a bicyclist. This information would be useful in selecting proper gearing or perhaps finding an alternate route avoiding steep hills. Another useful feature of the MapMyRide Web service is the Cue Note/Driving (printed turn-by-turn route directions) and the 3D (allows the viewer to 'fly-through' the route) buttons below the elevation profile. These options are not available on the other Web services.

All three Web services allow a posted ride to be private or public. If a route is made public, then anyone can view the route's details and make comments (some Web services do require an account for leaving comments). Another option is to locate new routes by searching across all mapped routes contributed by a specific person, near a specific town, or within a zip code. In Figure 4, MapMyRide shows that a total of 202 public routes were mapped near Athens, Ohio. The numbered blue icons indicate the number of mapped routes that are available starting from a specific location (e.g., 99 begin in Athens and 17 start in The Plains). Icons can also be inserted into

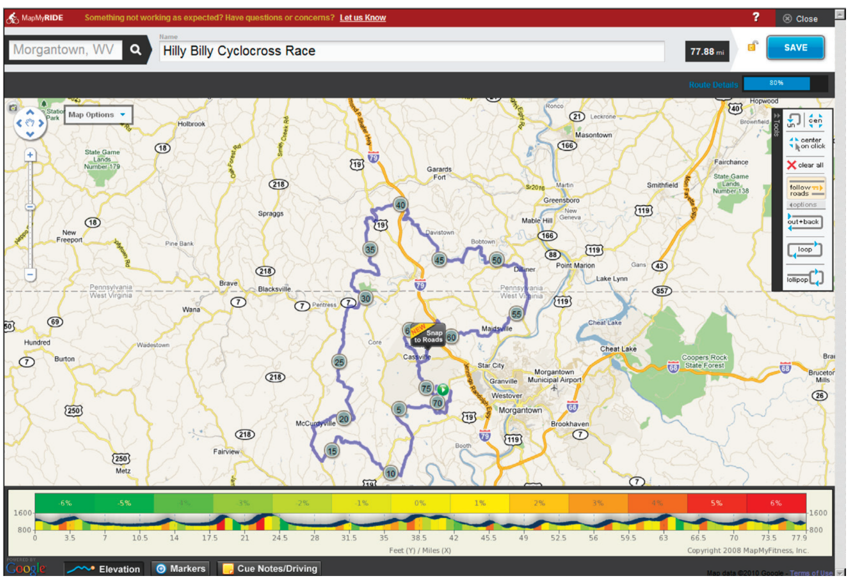

Figure 3. An illustration of the search for routes function in MapMyRide.

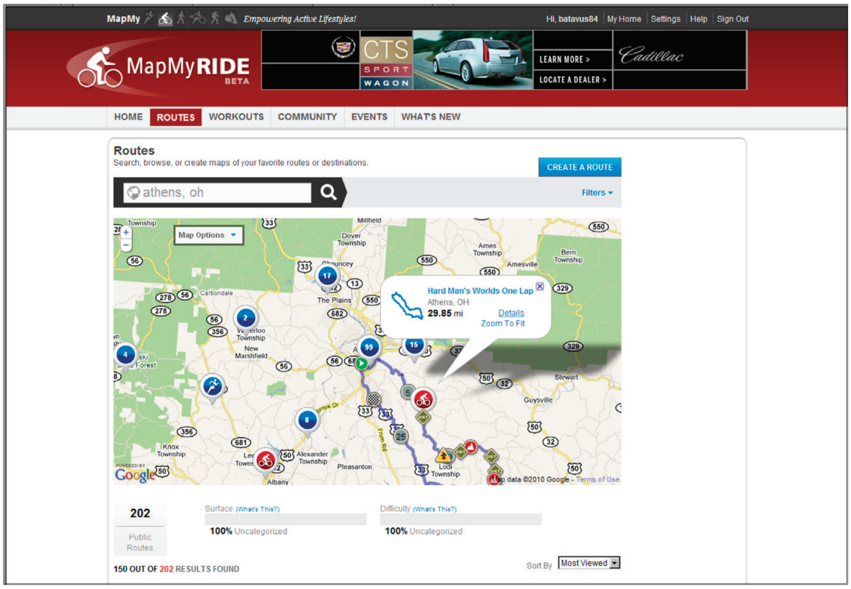

Figure 4. An illustration of the map editor environment for MapMyRide.

a route alerting other bicyclists about changing route conditions (e.g., a road changes to dirt or a steep climb). Other options include embedding images or video into the route for others to view and allowing users to indicate which routes they liked or disliked providing a tally for viewers (e.g., thumbs up or thumbs down).

Data Collection and Dissemination

Since VGI is fundamentally focused on users contributing their personal information to the broader community, data accuracy is important. Figure 5 shows a portion of a race in which I competed (a 20-lap criterium) using the Garmin Edge 705. The GPS tracings show that I apparently wandered quite a bit through the various turns, possibly taking 'shortcuts' across the curbs and sidewalks. Seeing a route like this one may raise questions as to the credibility of the person who rode the route (e.g., did he cheat during the race by taking shortcuts?). In part, this wandering has to do with the device's sampling of the GPS signal, which cannot be altered, as well as the error of the Edge device (the product's documentation reports an error of ±19 feet). Although there is a common belief in the accuracy of GPS and Google Maps, accuracy remains a concern with these two technologies.

Accuracy is also a factor in how the creator perceives the ride. For example, in MapMyRide, a contributor can rate a ride in terms of the level of difficulty. Given the vast fitness levels between cyclists, what is an easy ride to someone may be taxing to another. A user could comment on a 65 mile ride as 'easy'. Another cyclist may read this rating and attempt the ride only to abandon half way through to avoid personal injury. The disgruntled cyclist has the option to leave a negative comment about the claimed easiness of the ride as a warning to others as to the perceived difficulty of the route.

Accuracy also impacts the route details. To illustrate, MapMyRide's Map Editor function allows a user to draw a route on screen and then

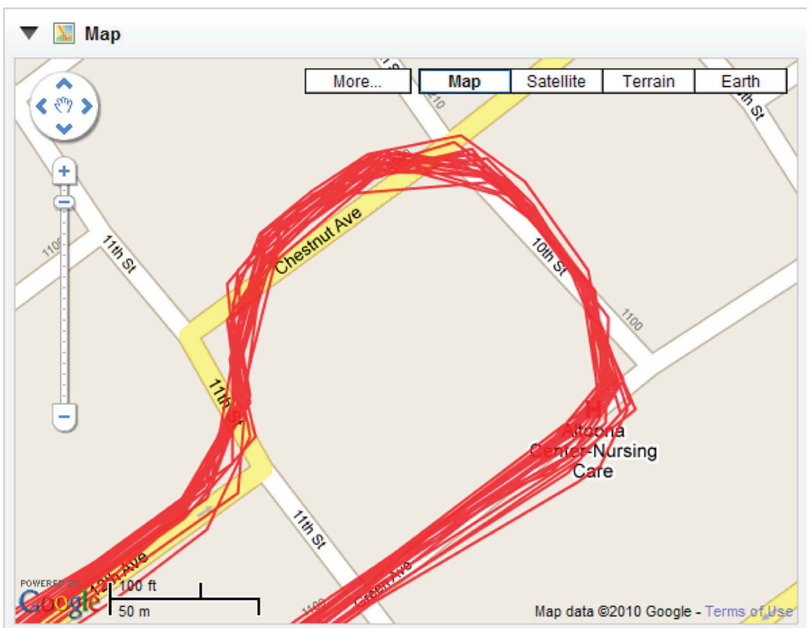

Figure 5. Routes taken during a race in Garmin Connect.

post that route for others to view. This process can be problematic. If the route creator only used the editor function and did not ride the route, then any important local road conditions, possible errors in the Google base map information, or improper route directions would not be apparent. For example, from personal experience, a route I once followed instructed me to travel along a road that went through private property. Large and threatening no trespassing signs appeared at the entrance of a gun club; judiciously, I turned back. In another case, I followed a route that clearly appeared in Google's base information; however, when I approached the intersection where I was expecting a turn, no such road existed.

Characterization of Knowledge

These and other cycling specific Web services can be described as contributing to existing knowledge and creating new knowledge. Through a 'patchwork' process, these and other bicycling Web services have developed an ever expanding database of routes. As new individuals join and existing members add more routes, the size of the database increases, thus contributing to existing knowledge. An interesting characteristic of these Web services is that, unlike a GIS geospatial data clearinghouse, the same route can be uploaded numerous times (by the same individual or by different individuals). Each route then is a separate entity complete with a host of ride statistics for all to view.

Why is it that people volunteer copious amounts of personal information and dedicate large amounts of time to this activity? The total miles logged announcement on the Garmin Connect home page (Figure 6) makes joining the Garmin community appealing; by so doing one is connecting with like-minded energetic and athletic people who log millions of miles, burn tons of calories, and map a lot of routes. By joining, one feels part of a social network of friends that are digitally connected and working toward a common goal of riding their bikes. Certainly, sharing mapped routes with friends is a typical practice and Web services like Garmin Connect makes sharing convenient. In another respect, self-promotion or vanity can also explain some of the motivation. By sharing route information, there is a feeling of self promotion in seeing one's route displayed along with many others (e.g., riding a previously posted route faster than the route's creator) and that one's efforts are contributing to something larger than the individual.

In many respects, the posting of information to a Web service creates new knowledge. It is common for bicycle race promoters to upload an upcoming race route to a Web service. Details of the route, turn-by-turn directions, and an elevation profile are extremely valuable knowledge to the racer. I have viewed an uploaded race route learning the total mileage, seen the changes in the percent grade, selected the appropriate gearing, and conferred with teammates on an appropriate race strategy. On a few occasions, I have lived close enough

Figure 6. Start up screen for Garmin Connect (accessed March 2, 2011).

to the race course that I have downloaded the route onto my GPS device and pre-ridden the route, thus gaining first-hand knowledge of the course and becoming familiar with any road hazards such as pot holes, gravel, or aggressive dogs.

Despite the benefit of contributing to or creating new knowledge one question remains: What's the value of the knowledge? Since all three Web services allow users to set a route as private or public, others in the bicycling community can view the route and make comments indicating which routes they liked or disliked (e.g., a thumbs up or thumbs down). A viewer can also leave a short statement about the route. The route creator can also view summary data, including the number of viewers that have ridden the route, whether the route ranks as a top five favorite, or include the route as part of their regular workout. However, from my personal observation, many of the routes on MapMyRide have never been viewed by anyone and are not rated. In fact, none of the publicly available routes that I created have received feedback. These routes simply occupy storage space on a server. What is lacking is concrete evidence whether the availability of bicycle route information over these Web services really helps other bicyclists make informed decisions, for example, in planning a ride. Research is needed that investigates what motivates bicyclists to use these Web services and what specific benefits, if any, are derived. Technology appears to be driving the functionality of these Web services without much feedback from the bicycling community as to these services' value.

Discussion

Two camps seem to exist regarding VGI. On the one hand, Sui (2008) is optimistic about VGI's future, suggesting that VGI enables mapping at the local level, thus challenging the monopoly held by institutional mapping agencies. Goodchild (2008) concurs, and explains that having a large number of individuals sensing and mapping information is more cost effective than the production efforts of, for example, institutional cartographic agencies. To be cost effective, however, does not necessarily connote that information is of poor quality and inaccurate. In fact, Goodchild believes that individuals at the local level are more attached to their immediate surroundings and are more apt to recognize and report errors. With VGI, those errors can get fixed much more rapidly than through a more 'professional' cartographic hierarchy.

Keen (2007), however, takes a more pessimistic view of how the Web, particularly Web 2.0 and user generated content, has facilitated the sharing of individuals' experiences. The Web provided a promise of enabling individuals with the power to deliver the truth, unbiased opinions, and a deeper sense of information. However, Keen argues that this is all a smokescreen and that the real outcomes are a reduction in culture, reliable news, and a chaos of useless information. Moreover, Keen (2007, p. 16) warns that the most "chilling reality in this brave new digital epoch is the blurring, obfuscation, and even disappearance of truth."

As evidenced above, VGI is very much alive and prospering in the bicycling community. The very existence of Garmin Connect, Bicycling-Trimble Outdoors, MapMyRide and other Web services indicates that the bicycling community recognizes that there is worth in the VGI concept and the Web services recognize there is a need among the cycling community. MapMyRide routinely sends out messages indicating that new route tools have been added or that improved functionality is available for testing. User forums on MapMyRide and other Websites are provided that allows members to ask questions and seek answers about the use of the services.

From my perspective, using these services has added to my racing performance. As an amateur racer, it is useful to map each route and create an inventory of my rides and races. Having experienced both sides of route recording technology, to download and quickly see where and how far you rode or raced that day does bring a certain level of satisfaction of accomplishment. Similarly, training tools available through these Web services track fitness levels throughout each racing season and across years. By carefully monitoring fitness data (e.g., heart rate, power output, and cadence), my racing performance has increased. I have found it possible to target specific areas of weakness and design a training program that improves those weaknesses. For instance, one of my weaknesses is climbing. I have been able to note a strong correlation between percent grades of 8% and higher and a notable increases in my heart rate. This combination produces a negative outcome to my racing performance. In order to mitigate this weakness, I have engaged in a specific weight training program to strengthen my climbing abilities.

Conclusion

In this article, I focus on the use of VGI in the bicycling community, whose involvement in VGI to this point has been largely ignored in the literature. To help demonstrate the degree to which VGI has been integrated into the bicycling community three bicycling specific Web services (Garmin Connect, Bicycling-Trimble Outdoors, and MapMyRide) were examined. These three bicycling Web services were used as a backdrop to frame discussion of VGI challenges focusing on Elwood's (2008) three themes (technologies that facilitate VGI, data collection and dissemination, and characterization of knowledge).

Improvements in technology make it easy for novice computer users to use these Web services and upload GPS route data, see basic ride data, and map out their route. These Web services also create community, with users sharing information and commenting to other users on their route. The ease of use clearly demonstrates how simplified user interfaces have facilitated the popularity and use of VGI for bicyclists. Accuracy of the route data collection and dissemination process and the resulting posted information was another theme. Clearly, the sharing of personal geospatial data does not have the quality control measures, metadata, or data model that is common with a GIS data clearinghouse. Despite the appeal of these bicycling Web services, accuracy issues are still present (i.e., base map information provided by Google is not always up-to-date, or is simply wrong). Bicyclists posting their route information can characterize that knowledge as adding to existing knowledge or generating new knowledge. Riders who post their route information are adding to existing knowledge and are helping to build a considerable database on bike riding habits (e.g., ride times, frequency of rides, and numbers of postings). Race promoters who share an upcoming race route on a Web service generate new knowledge among the racing community. Armed with this new knowledge, racers can make an informed decision regarding their preparation for the upcoming race.

Despite the apparent benefits these Web services bring to the bicycling community the following point is clear: Individuals spend considerable time and effort uploading and sharing their ride information. However, much of the uploaded information is generally neither viewed by nor benefits anyone. Aside from some self promotion and fascination with the ever changing technology tools, there is little evidence to document the value that VGI provides to the bicycling community. To help uncover the value of VGI to the bicyclist, what is needed is additional research which would specifically examine the motivation behind why bicyclists upload their information, what tangible value is associated with products of their uploaded information, and the degree to which VGI facilitates this process. Ultimately, solving these basic questions would lead to a better understanding of VGI's importance not only to the bicycling community but could also be extended to other user groups.

It is clear that VGI (or whatever term is applied in the years to come) will continue to be a major factor in the mapping and sharing of geographic information not only for the bicycling community but also for other user communities who have yet to discover VGI's value. Without further research, however, technology will continue to add additional flashy tools and features to the user interface and we will still understand little about the role and value that VGI plays in the dissemination of personal geographic information.

REFERENCES

Campbell, A., S.B. Eisenman, N.D. Lane, E. Miluzzo, R.A. Peterson, Hong Lu, Xiao Zheng, M. Musolesi, K. Fodor, G. Ahn (2008). The Rise of People-Centric Sensing. *IEEE Internet Computing* 8: 12-21.

Chambers, R. 2006. Participatory Mapping and Geographic Information Systems: Whose Map? Who is Empowered and Who Disempowered? Who Gains and Who Loses? *The Electronic Systems in Developing Countries* 25 (2): 1-11.

Dangermond, J. 1995. Public Data Access: Another Side of GIS Data Sharing. In: H. Onsrud and G. Rushton (eds.), *Sharing Geographic Information*, pp. 331-339. New Brunswick: Center for Urban Policy Research.

Dobson, J. and P. Fisher. 2003. GeoSlavery. *IEEE Technology and Society Magazine*, Spring, 47-52.

Eisenmann, S., E. Miluzzo, N. Lane, R. Peterson, G. Ahn and A. Campbell. 2009. BikeNet: A mobile Sensing System for Cyclist Experience Mapping. *ACM Transactions on Sensor Networks* 6(1): 1-39.

Elwood, S. 2008. Volunteered Geographic Information: Future Research Directions Motivated by Critical, Participatory, and Feminist GIS. *GeoJournal* 72(3-4): 173-183.

Flanagin, A. and M. Metzger. 2008. The credibility of volunteered geographic information. *GeoJournal* 72(3-4): 137-148.

Goodchild, M. 2009. NeoGeography and the Nature of Geographic Expertise. *Journal of Location Based Services* 3(2), 82-96.

Goodchild, M. 2008. Commentary: Whither VGI? *GeoJournal* 72(3-4): 239-244.

Goodchild, M. 2007. Citizens as Sensors: The World of Volunteered Geography. *GeoJournal* 69: 211-221.

Keen, A. 2007. *The Cult of the Amateur: How Today's Internet Is Killing our Culture*. New York: Doubleday.

Krygier, J. 1999. World Wide Mapping and GIS: An Application for Public Participatin. *Cartographic Perspectives* 33:66-67.

Lauriault, T. and J. Wood. 2009. GPS Tracings -- Personal Cartographies. *The Cartographic Journal* 46(4): 360-365.

Liu, S. and L. Palen. 2010. The New Cartographers: Crisis Map Mashups and the Emergence of Neogographic Practice. *Cartography and Geographic Information Science* 37(1): 69-90.

Nordheimer, J. 1995, January 11. 'Vigilante' Attack in New Jersey Is Linked to Sex-Offenders Law. *The New York Times*. Online: *http://www.nytimes.com/1995/01/11/nyregion/vigilante-attack-in-new-jersey-is-linked-to-sex-offenders-law.html* (accessed 26 February 2011)

O'Reilly, T. 2005. *What is the Web 2.0*. Online: from O'Reilly Web 2.0: *http://www.oreilly-net.com/pub/a/oreilly/tim/news/2005/09/30/what-is-the-Web-20.html* (accessed 26 February 2011).

O'Reilly, T. and J. Battelle. 2009. *"Web squared: Web 2.0 five years on."* Web 2.0 Summit, San Francisco, CA. Online: *http://assets.en.oreilly.com/1/event/28/Web2009_Websquared-whitepaper.pdf.* (accessed 26 February 2011).

Priedhorsky, R., B. Jordan and L. Terveen. 2007. How a Personalized Geowiki can Help Bicyclists Share Information More Effectively. *ACM Transactions on Sensor Networks*, pp. 93-98.

Reddy, S., K. Shilton, G. Denisoy, C. Cenizal, D. Estrin and M. Srivastava. 2010. Biketastics: Sensing and Mapping for Better Biking. In: *Proceedings of the 28th International Conference on Human Factors in Computing Systems* (pp. 1817-1820). Atlanta, GA: Conference on Human Factors in Computing Systems.

Sui, D. 2008. "Is Neogeography Hype or Hope?" *GeoWorld* 21(3): 16-17.

Tulloch, D. 2008. Is VGI participation? From vernal pools to video games. *GeoJournal* 72(3-4): 161-171.

Turner, A. 2006. *Introduction to Neogeography. Sebastol*, California: O'Reilly Media, Inc.

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Teaching Mapping for Digital Natives: New Pedagogical Ideas for Undergraduate Cartography Education

Francis Harvey and Jennifer Kotting

ABSTRACT: The current generation of US students engaging with cartography has always had some form of access to computing technologies. Further, this generation has always known a world with networked computer capabilities – the Internet and World Wide Web. Their experience of cartography is largely through fleeting representations shown on a variety of display screens, thereby encountering information differently than most of their instructors. Teaching cartography to these "digital natives" consequently challenges teachers to engage increasing levels of experience and knowledge of technology while assuring fundamental understanding of cartographic concepts and analysis techniques.

Although GIS is used in a vast range of fields, we believe many students are discouraged from programs and courses oriented towards educating cartographic specialists. However, general interest in mapping has never been as significant a part of American culture as it is today. In spite of accessible modes of digital mapping now widely available, introducing cartographic fundamentals retains great significance for undergraduate cartography education. In this paper we present a new pedagogical model for undergraduate cartography education that introduces students finding curiousity in mapping, but lacking desire to become cartographic specialists, to mapping. This model enables undergraduate students to learn fundamentals and begin to reflect critically on the concepts and techniques of modern cartography. Our example stems from a class that systematically addresses barriers to learning and mapping through active-learning based approaches in an interactive classroom. The active-learning approach involves significant engagements with the potentials and challenges of modern cartography in the information age by embracing inquiry-based pedagogical methods and learning with and about mapping.

KEYWORDS: pedagody in geography, cartographic education, modern cartgraphy, mapping

New Wine and New Bottles: Pedagogy for Mapping in the Information Age

Do you remember the first map you used? Was it online or on a computer? Chances are if you were born before 1980 in the United States it was a paper map or atlas. If you were born after 1980, it probably was a digital map, maybe online, maybe from a CD-ROM or DVD. If you were born after 1990, almost every map you have used before starting college was likely in a digital format, displayed on screens varying enormously in size. The majority of today's students entering US colleges belong to the last group. These "digital natives" (Prensky 2001) have grown up not only surrounded with digital maps, but in a world where digital communication and information is intrinsic to their day-to-day lives (Turkle 1995; Turkle 1997). In her seminal book Life on Screen, Sherry Turkle shows that the digital age is emblematic of all technology in its ability to extend human capabilities (Turkle 1995, p. 22). New forms of information and new ways to represent information are becoming available, all the while becoming more accessible and 'user-friendly.'

In the context of cartographic education, this vast change has significant implications for teaching and learning about maps. Students are not only approaching cartography differently then previous generations, but thinking about maps in a largely interactive context. As reflected in the media, current mapping

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products accessible to the general public tend to provide fleeting engagements with ubiquitous representations of cartographic information that are useful for everyday activities. Students today have different expectations for learning with and about mapping that reflect this exposure, including digital technologies such as GPS for cars, locational technologies in phones, and similar application-driven software increasingly available online and on mobile devices. Academic programs are working to meet the resulting demands and challenges. We describe in this article a new course called Digital Mapping aimed at introducing this new generation of learners to basic cartographic concepts. A key emphasis in this course is that we provide instruction without the intention of providing specialist cartographic training.

In education, much has been written about pedagogical changes arising with digital natives, particularly in the context of K-12 curriculum reform (Rod et al. 2010; Johansson 2003). In this article, we consider pedagogical changes in higher education and specific opportunities to support entry-level undergraduate cartographic education for the diverse and growing number of students interested in mapping (DiBiase, 2007). We examine the context of cartographic education, and pedagogical approaches for teaching digital natives basics of cartography. In the paper, we present a model for teaching mapping at the undergraduate level through active-learning approaches. We should point out, up front, that the pedagogical goal of our model is not to replace traditional cartographic education (as exemplified in Robinson 1960; Dent 1993; MacEachren 1994), but to supplement it with a course aimed at introducing digital natives to online-based approaches for producing maps in the computer age (Sui 2004).

We suggest in this article a specific type of course offering that expands upon existing academic programs in cartography with consideration of the backgrounds and approaches to learning of digital natives as well as changes in cartography. This type of course complements the breadth of knowledge and skills in traditional cartographic education, which is aimed at producing professional specialists and academics. Our model arises from the development and first-time experiences of teaching one single course. Through this course and others based on this model, we hope that more undergraduate students become further intrigued by cartography and geographic information processing through hands-on learning coupled with immediate successes in making maps, and continue to pursue course work in traditional cartographic courses. The active-learning approach we describe and apply to the teaching of mapping has a strong emphasis on teaching students how to make maps online and how to work through related cartographic concepts and challenges. Because of differences to 'traditional' cartography pedagogy, focused on training specialists, we look at this course as a new approach to introduce students to the underlying concepts and techniques of cartography compared to traditional map reading classes.

Training for Cartographic Specialists: Pedagogy and Textbooks

Like any discipline, cartography's evolution can be traced through its popular textbooks and other educational resources. Indeed, changes in many textbooks already account for change associated with the education of digital natives. Some of these books exemplify changes in coverage and approaches that correspond to the increased use of GIS. However, textbooks and other resources aimed to assist undergraduate educators in the structuring of their cartography courses continue to emphasize the training of specialists.

Since its publication in 2007, the Geographic Information Science and Technology Body of Knowledge (BoK), created by the University Consortium for Geographic Information Science (Dibiase 2007), has been an important reference for pedagogical discussions of curricula, certification, and competency testing. The BoK is often used to assess and modify the structure and coverage of existing courses, and to add new courses to GIS curricula. The BoK editors identify topics for the training of GIS specialists, "a comprehensive inventory of the GI S&T knowledge domain" (Dibiase 2007, p. 4), for use within the GI S&T education community, while at the same time assure pedagogy that prepares an adequate workforce. Cartography and Visualization (CV) is one of the 10 knowledge areas represented in the BoK. Six units, three of which are core units, comprise the knowledge area CV. Twenty-seven topics, defined through 205 educational objectives, comprise the six units related to cartography and visualization.

The engagement with cartography in the BoK follows a different approach than the Core Curriculum, developed about a decade earlier under the guidance of the National Center for Geographic Information Analysis (NCGIA 2000). The first version of the Core Curriculum, widely taken up as the benchmark for developing, transitioning, and revising GIS curricula, was published in 1990, and followed in 1995 by partially revised version for distribution on the World Wide Web. In distinction to the BoK organization, many cartographic topics are folded into other topics, although a sub-section on cartography and visualization can also be found. But for example, projections are included in the section titled "Geographic Concepts".

Dan Sui critiques the Core Curriculum and its intellectual organization for teaching GIS, adding reasons for its eventual abandonment (Sui 1995). Sui focuses on the inventory-nature of the model curriculum and lack of overarching principles to facilitate teaching of geographic information concepts. Noteworthy among approaches that offered a more synoptic pedagogical framework, with more emphasis on cartographic concepts and techniques, is Kenneth Foote's The Geographer's Craft, launched at about the same time as a new approach to teaching geographical methods in the liberal arts curriculum (Foote 1997).

Textbooks and publications focused on cartography of the same period mark the significant transition from training in dark room cartography to computerized cartography. Dent's Cartography: Thematic map design (1992) is an example of a textbook coming out of the former environment and Jones's Geographical information systems and computer cartography marks a transition to the more integral use of GIS in cartography. MacEachren's Some Truth with Maps (1994) and Monmonnier's publications, including How to lie with maps (1996) engage the underlying conceptual shifts in cartography, recasting cartographic knowledge and skills for computer-based cartography. Slocum's Thematic cartography and geographic visualization (2005) and the 2008 update written with McMaster, Kessler, and Howard, Thematic cartography and geovisualization also reflect the shift from manual cartographic practice to the increased reliance on computers; Thematic cartography and geovisualization continues to evolve, now already in its third edition. Kraak and Brown's Web cartography (2001) also points to these changes, with its consideration of the proliferation of poorly designed, inadequate, and misleading maps appearing with the mushrooming of GIS.

Pedagogical Concepts for Introducing Digital Natives to Cartographic Fundamentals

Active learning responds to ways digital natives live and learn now. These learners are shaped and influenced in countless ways by the Internet and digital technologies. We see their skill sets developing quickly in response to newly available technologies, such as online chats, free online encyclopedias, and even exposure to, GPS units, and other locational devices and applications. A course like Digital Mapping helps students learn more about the cartography that they have already engaged with, while introducing them to the fundamentals of cartography. The active-learning model of the Digital Mapping course connects the skills they already have with new skills and develops new prospects for their application (Prensky 2001). In this course, we illuminate the usefulness of digital mapping for research, work, and fun, and fill some of the gaps in students' current knowledge in order to develop analytical and useful skills for working with maps. Delivering active learning lessons through interactive hands-on activities adds excitement and, approached with simplicity, supports the development of students' skills.

Digital natives' styles of learning may seem fast-paced, casual, overly playful and visual, even frantic in comparison to classroom experiences more familiar to their teachers. The divide is not just one of terminology or speed, but also in predominant styles of learning. Marc Prensky, a leader in the field of new educational technologies, describes the changing learning styles:

> *"Digital Natives are used to receiving information really fast. They like to parallel process and multi-task. They prefer their graphics before their text rather than the opposite. They prefer random access (like hypertext). They function best when networked. They thrive on instant gratification and frequent rewards. They prefer games to 'serious' work." (Prensky 2001, p. 2)*

Active-learning approaches are well-suited for this style of learning because they support each individual's work approach at the same time providing guidance and a framework for learning. The approach we describe in this article is different from lectures/labs and other traditional modes of learning in which students are expected to receive knowledge in one setting and apply it later. Active learning requires that they construct the knowledge through sense-making, where each student creates a different a coherent mental representation of the knowledge augmented through multiple interactions with material, instructors, and other students (Mayer 2001, p. 13). In an active learning classroom environment, the teacher adopts the role of facilitator for the student's learning process with specific goals in mind following inquiry-based, contextually-rich models of learning: "development of higher-order, inquiry-process skills," in-depth data explorations, and "giving greater meaning to the work of student researchers" (Baker 2005, pp. 44-45).

Because digital natives are diverse in a variety of ways, we employ a scaffolding strategy to support diverse learning approaches. Scaffolding is an educational approach to organizing curricula and syllabi using concrete elements of support, such as surveys, experiences, and assignments, with intentional references to students' preconceptions and diverse knowledges. Scaffolding creates a framework for supporting each student's learning approach (Hogan and Pressley 1997). Following the scaffolding strategy we create a structure for lessons that is flexible enough for individual learning strategies and outcomes. Through the combination of active learning and scaffolding we have addressed the challenges of teaching introductory level cartography fundamentals to eclectic students. The next section of the paper describes the various specific techniques we developed.

Application of Active Learning and Scaffolding to a Mapping Course for Digital Natives

Our course design focuses on the uses of digital technologies to learn basics of cartography, create effective online maps, and use online mapping applications. Figure 1 illustrates our implementation of scaffolding in the digital mapping course. The course design is progressive and provides a clear framework and feedback for students at various levels of ability, both hallmarks of the scaffolding technique. The first half of the course involves a series of lessons to develop technical knowledge and basic mapping skills and the second half focuses on group projects in which students develop a project emphasizing the creation of on-line interactive

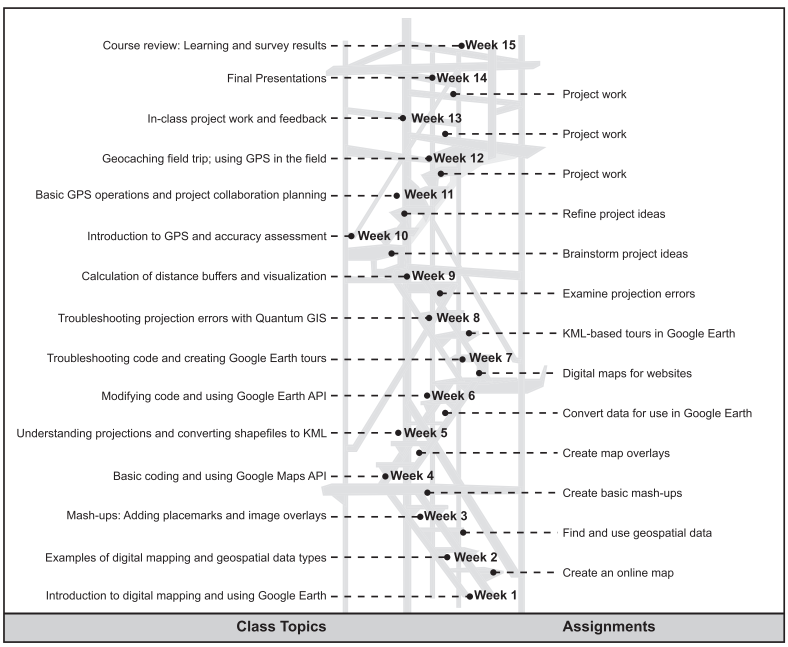

Figure 1. Scaffolding through a semester of Digital Mapping. Scaffolding provides resources and organizes the activities to support individual learning styles.

maps. An example of the progressive nature of the introduction of topics is the introduction and use of GPS for data collection in weeks 11 and 12 (see Figure 1).

Encountering selected general concepts of cartography through active learning (Bonwell 1997), students contextualize the subject matter and envision strategies to solve a problem at hand, thereby applying and understanding conceptual issues. Through the scaffolding of knowledge and skills, they develop a framework of the underlying cartographic fundamentals. Following active learning pedagogical concepts, we organize the classroom teaching methodology around interactive assignments that deal with obstacles to completing work through engaging problems, instead of explaining concepts from the ground up. This is referred to as evolution instead of revolution in educational literature (Rød et al. 2010). In other words, when teaching about technologies that are constantly undergoing evolution themselves, teaching methodology must be flexible to those changes, meaning no ideal curriculum is achieved and finished. Instead, when we encounter problems, we use them as an opportunity to demonstrate how to solve them creatively through reference to conceptual issues and in a collaborative process. The three main obstacles to this approach we encounter are 1) getting students interested, especially in the more challenging aspects of cartography; 2) developing the necessary hardware and software skills, which may still end up being unequal from student to student; and 3) dealing with technology and overcoming the related learning curve challenges for both teachers and students.

During a class, students work on applications while tackling real life problems (see Figure 2 for an image of students starting an assignment). For example, we used kml files in Google Earth showing the crisis in Haiti as it was ongoing and we invited a professor who demonstrated global changes in forest cover using Google Earth. Finally, we seek a balance between technical topics and applications so that students acquire a skill set that will serve them now and in the future (Kemp et al. 1992). We engage students through discussions, game playing, decision-making, multimedia, and inquiry-based learning (Prensky 2001). We arrange discussions at the beginning of classes and at other key moments so that students can talk in small groups, and develop rapport and familiarity with other students without having to stand out in the entire class. Game playing takes place on occasions when it helps teach students the skills they needed or introduce topics for class discussion. For example, students participate in a Geocaching field trip that scaffolds learned techniques of navigating with a geobrowser with orientation on the ground. Students had previously learned how symbolize features; now they were applying that knowledge and skills. Finally, for group project work, which is a significant portion of the course, we rely on an inquiry-based teaching strategy that focusses on problem solving. In this part of the class, we introduce problems related to the projects that students solved through small group exercises, short-term collaborative development and design of solutions to a problem at that phase of the project.

Some specific implementations of the active-learning and scaffolding techniques include the following. The introduction to KML starts with some simple script editing assignments that familiarize students with script editing and introduces them to file management. Over time, the complexity of the scripts increases, requiring drawing on skills learnt earlier and applying them to more challenging scripting and file management activities. The importance of accuracy only comes in week 10, after a thorough introduction to KML and an important assignment involving projection errors. This assignment gives the students the knowledge and skills acquired through problem solving to connect concepts of accuracy to their own experiences.

Surveys and feedback

While the implementation of the approach involving broadly engaging course topics is important to active learning, it is also crucial for each student to receive guidance through the course starting with a self-assessment of what they know at the beginning of the course. We use anonymous surveys as the vehicle for supporting ongoing feedback between students and instructors. In the Digital Mapping class these surveys provide instructors with insights into challenges and successes students face in the class and feedback on student achievement. The results guide the planning and revision of future lessons and provide clarification to students who had struggled with following principles from active learning pedagogy (Hartman 2002). Assessments through the anonymous surveys occur in an approximately two week interval. Most of the assessment questions stay the same over the course of the semester. These questions deal with engagement in class, satisfaction with learning, and self-assessment of competency using and understanding mapping. Several questions are varied according to the topic of the preceding weeks. These questions sought to get students to reflect on explicit learning outcomes and make individual connections to learning goals.

Figure 2. Students at the beginning of a class meeting.

In the Digital Mapping course, the semester starts with a broad assessment of students' Internet knowledge and skills in cartography and GIS-related areas. The results are presented in the second class to help students realize the breadth of backgrounds and experiences found in a class with 38 students. Students with more limited programming and similar experiences with information technologies, the large majority, recognize they are not alone. We point out the importance of supporting their learning and hasten to explain to students with more experience in these areas the benefits of explaining practical and conceptual topics to other students. We also encourage collaboration by awarding points for in-class and online questioning and providing answers. This becomes the first layer of each student's scaffold and facilitates a collaborative approach to working on assignments.

Problem-solving hands-on learning assignments

In the classroom activities, active-learning approach emphasizes hands-on graphical oriented learning, using "both words and pictures" (Mayer 2001, p. 1). We include the use of new technologies, especially GPS receivers and online mapping to aid learning. Learning kml scripting connects textual manipulation with visual feedback, for example the successfullly locating a placemark through scripting the latitude and longitude locations. We also introduce fundamentals of cartography in this way. For example, students learn principles of projections and datums not through multiple lectures, but through a 10 minute introduction and then they must work through an exercise in which they introduce an error in the datum conversion. They must visually identify the error and then correctly complete a modification of the datum in order to combine data from different sources. As discussed earlier, this problem-solving experience that merges graphical and textual modes of interaction, is the basis for a later assignment involving basic concepts of accuracy.

Group interaction facilitation

The novel physical arrangement of the classroom supports active learning. The spatial arrangement of the classroom, round tables for 6-8 students and no defined lectern nor desk replaces the front-facing orientation of most classrooms with a nodal arrangement. Projectors are available for displaying material on multiple screens in the room (the multiple projectors however were not functional during the class). This spatial arrangement facilitates engaging the students in groups and individually for active learning (see Figure 2).

To assure ample opportunities to engage, during class we generally use the projector and prepared presentations very little, opting instead to distribute handouts at the beginning of class, verbally reviewing the topic and activity, and setting out students on a small related task for a short time, 10 minutes at most, e.g., finding projection information in state provided metadata, before engaging the entire class with some discussion questions about conceptual topics. Students summarized what they had found and field questions from other students and the instructors. We would follow with a brief presentation to connect to the concepts of the day (e.g., projections and datums) and then laying out a more involved activity (e.g., projecting data from UTM to latitude/longititude coordinates and importing the data into Google Earth). During the rest of the meeting time, two hours in total, the two instructors assisted the students with questions. About 15 minutes before the end of the period, we reviewed the activity, asked for questions, and layed out the work for the assignment that students completed later. Figure 3 provides a detailed presentation of the organization of interactive-learning pedagogy in a class meeting.

Error messages: Dealing with inevitable problems

A significant challenge for active-learning pedagogy, lies not in cartographic concepts, but in technological access and literacy; two broad concepts often associated with the 'digital divide'[1]. This is the nature of working with information technology to teach mapping. Digital natives bring an awareness of the digital divide to the class.

[1] Although the term 'digital divide' first came into use in the 1990's within a political context, we refer to Mehra et al, 2004.

> *"Digital technology access is unequal by its nature—or at least by the way we make and sell it—and always will be. We can set a floor – a set of minimum specifications – but some people will always want more. There is a huge variety of choices available, and each device is a set of trade-offs, enabling every person to get the feature set he or she prefers and can afford. Few of us have the same phones, computers, stereos, speakers, etc, nor would we want to." (Prensky 2009, p. 2)*

Prensky makes recommendations to address these problems, which we incorporated into the design of the course. His first point is to let students use the technology available in the classroom. Second, structure classwork and homework so that students can have opportunities to share what they do have. (for instance, our students often shared USB drives, which is what USB drives are for, as part of exercises with partners and groups). Third, provide access to labs on campus that have software they'll need. (We increased access time to school laptops by having students sign them out in a lab so they could use software loaded for the class as long as the nearby computer lab was open.) Fourth, and finally, help students find cheap or free hardware and software and try to use open source software.

The key strategy we found for classes to address the digital access and literacy is to ensure laptop computers are available for all students in the classroom in case they needed to use a computer with the required software. While a small number of students provide their own computers and download any software needed for the activity and assignment, two-thirds of the students regularly rely on the provided laptop computers.

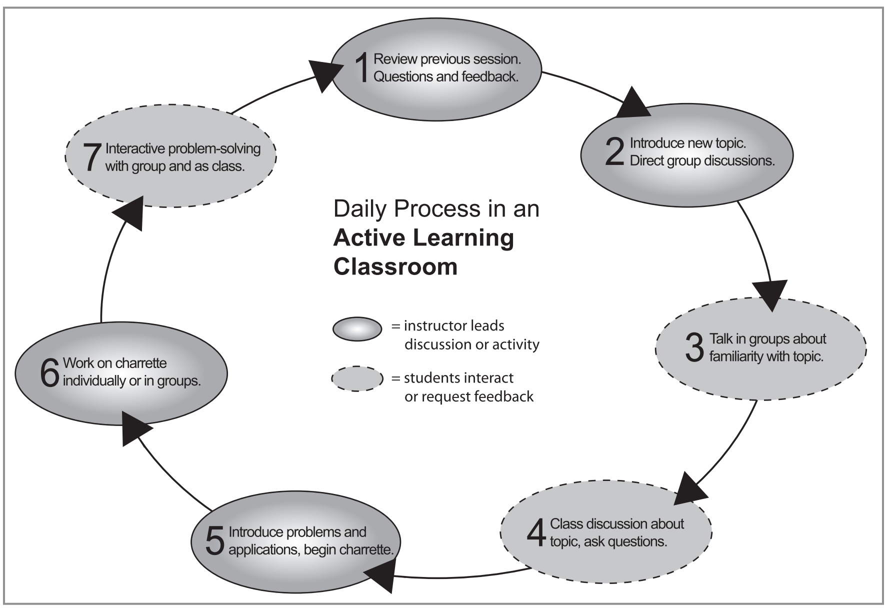

Figure 3. Organization of classroom activities showing the process of typical events in the active learning class meeting.

Conclusion

Although many GIS undergraduate programs are engaging students in new ways with courses covering online mapping and cartographic basics in various ways, we see active learning and scaffolding provide enhancements for reaching many students who stand to benefit from better knowledge of cartography, but are unlikely to become cartographic or GIS specialists. Through courses like the example of Digital Mapping we discuss, we see an opportunity for programs to fill a gap in current curricula and reach more undergraduates who already have an interest in mapping but may not have the desire or aspiration to complete a GIS-related degree program. Cartographic skills and expertise should benefit the non-GIS specialists who will be making online maps in the course of their work. In conclusion, we can say the Digital Mapping course we describe in this article reflects four related principles for this new teaching environment:

- The course provides cartographic education for students who had never (knowingly) created a map or, more realistically, students at a variety of skill levels.
- The course is interactive and project-focused rather than lecture or textbook-focused.
- The course invites non-GIS students to learn how to create quick and simple map mashups with the ability to do and learn more based on their individual acquisition of skills.
- The course teaches fundamental cartographic concepts through technologies that students are likely to use, but also one that teaches students to connect their current knowledge with possibilities for creating informative maps.

In summary, this article proposes the merging of active learning and scaffolding pedagogies in the interactive classroom offers a helpful pedagogy for introducing digital natives to cartography and preparing them for the use of mapping in a broad array of fields.

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REFERENCES

Andrienko, G. L. and N. V. Andrienko. 1999. Interactive maps for visual data exploration. International *Journal of Geographic Information Science* 13(4): 355-374.

Baker, T. R. 2005. Internet-Based GIS Mapping in Support of K-12 Education. *The Professional Geographer* 57(1): 44-50.

Bonwell, C. 1997. Using active learning as assessment in the postsecondary classroom. Clearing House 71(2): 73-77.

Clay, M. and C. Cazden. 1990. *A Vygotskian interpretation of Reading Recovery and applications of sociohistorical psychology. Vygotsky and education: Instructional implications.* L. C. Moll. Cambridge, Cambridge University Press: 206-222.

Dent, B. D. 1993. *Thematic Map Design*. Dubuque, IA, Wm. C. Brown.

Dibiase, D. 2007. *Geographic Information Science and Technology Body of Knowledge*. Washington DC, Association of American Geographers.

Dolence, M. and D. Norris. 1995. *Transforming Higher Education: A Vision of Learning in the 21st Century*. Ann Arbor, Society for College and University Planning.

Foote, K. 1997. The Geographer's Craft: Teaching GIS in the Web. *Transactions in GIS* 2(2): 137-150.

Grunert, J. 1997. *The Course Syllabus. A Learning-Centered Approach*. Bolton, MA, AnkerPublishing Company, Inc.

Halpern, D. F. (ed.) 1994. *Changing the College Classroom. New Teaching and Learning Strategies for an Increasingly Complex World*. San Francisco, Jossey-Bass Publishers.

Hansen, C. B. 1994. *Questioning techniques for the active classroom. Changing the College Classroom. New Teaching and Learning Strategies for an Increasingly Complex World*. D.F. Halpern. San Francisco, Jossey-Bass Publishers: 93-106.

Hartman, H. 2002. *Human Learning and Instruction.* New York, NY, City College of City University of New York.

Hogan, K. and M. Pressley. 1997. *Scaffolding Student Learning: Instructional Approaches & Issues*. Cambridge, MA: Brookline Books, Inc.

Jenks, G. F. 1987. Cartographic Education in Today's Geography Departments: Thoughts after Forty Years. *Cartographica* 24(2): 112-117.

Johansson, T. 2003. *GIS in Teacher Education – Facilitating GIS Applications in Secondary School Geography. ScanGIS'2003* - The 9th Scandinavian Research Conference on Geographical Information Science. K. Virrantaus and H. Tveite. Espoo, Finland: 285- 293.

Kemp, K. K., M. F. Goodchild and R.F. Dodson. 1992. Teaching GIS in Geography. *Professional Geographer* 44(2): 191-201.

Kernighan, B. W. and D. M. Ritchie. 1988. *The C Programming Language*, Prentice Hall.

Lenhart, A. and E.A. K. Purcell. 2010. *Social Media and Young Adults. Social media and mobile internet use among teens and young adults*. Washington, D.C., Pew Internet & American Life Project.

Lloyd, W. J. 2001. Integrating GIS into the Undergraduate Learning Environment. *Journal of Geography* 100(5): 158-163.

MacEachren, A. M. 1994. *Some Truth with Maps: A Primer on Symbolization and Design*. Washington D. C., American Association of Geographers.

Mayer, R. E. 2001. *Multimedia Learning*. New York, Cambridge University Press.

National Center for Geographic Information and Analysis. 2000. *NCGIA Core Curriculum in GIScience*. Online: *http://www.ncgia.ucsb.edu/education/curricula/giscc/aboutgiscc.html* (accessed 19 June 2010).

Mehra, B., C. Merkel and A.P. Bishop. 2004. The internet for empowerment of minority and marginalized users. *New Media and Society* 6(6): 781-802.

Palfrey, J. and U. Gasser (2008). *Born Digital: Understanding the First Generation of Digital Natives*. Philadelphia, PA, Basic Books.

Prensky, M. 2001. Digital Natives, Digital Immigrants. *On the Horizon* 9(5).

Prensky, M. 2009. Let's Be 'Digital Multipliers': Eliminating the Digital Divide Is Something Educators Can Do. *Educational Technology* (Jan-Feb).

Robinson, A. 1960. *Elements of Cartography*. New York, Wiley.

Rød, J. K., W. Larsen and E. Nilsen. 2010. Learning Geography with GIS: Integrating GIS into upper secondary school geography curricula. *Norwegian Journal of Geography* 64: 21-35.

Sui, D. Z. 1995. A pedagogic framework to link GIS to the intellectual core of geography. *The Journal of Geography* 94(6): 578-591.

Sui, D. Z. 2004. GIS, cartography, and the "Third Culture": Geographic imaginations in the computer age. *Professional Geographer* 56(1): 62-72.

Turkle, S. 1995. *Life on the Screen: Identity in the Age of the Internet*. New York, Simon and Schuster.

Turkle, S. 1997. *Growing up in the culture of simulation. Beyond Calculation: The Next Fifty Years of Computing*. P. J. Denning and R. H. Metcalfe. New York, Springer Verlag. 93-104.

Wilkerson, L. and W. H. Gijselars (eds.). 1996. *New Directions for Teaching and Learning*. San Francisco, Jossey-Bass Publishers.

Wood, D. J., J. S. Bruner and G. Ross. 1976. The role of tutoring in problem solving. *Journal of Child Psychiatry and Psychology* 17(2): 89-100.

Yelland, N. and J. Masters. 2007. Rethinking scaffolding in the information age. *Computers and Education* 48: 362-382.

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Converging Themes in Cartography and Computer Games

Ola Ahlqvist

Abstract: Maps and games have a long history of co-evolution, and after many years of parallel and sometimes independent development, we see today a convergence of mapping and gaming technologies. This report presents five broad themes in current-day computer gaming and cartography, highlighting some of the connections between these two dynamic fields and arguing for the potential of combining modern cartographic theory, tools, and practice with gaming approaches.

Keywords: computer gaming, cartography, cartographic theory

Introduction

The history of games goes back at least as far the history of maps and cartography, with evidence of board games being played by humans for more than 5000 years (Whitehill 1999). Maps of different types have played an important role in many recreational games throughout history; treasure maps in board games, schematic reality-inspired maps in Monopoly, regular maps with game tracks on top, schoolyard replicas of continents and the world, maps of fantasy worlds and so on. Further testament to the prominent role of game maps in everyday culture is evidenced by the inclusion of the Carmen Sandiego Game Board in the Library of Congress and the American Congress on Surveying and Mapping (ACSM) online exhibition (*http://www.loc.gov/exhibits/maps/*). This report seeks to elaborate on the yet uncharted relationship between modern cartography and computer gaming, and suggest some current converging trends. For the purpose of this paper I will follow Smed and Hakonen (2003) and define a computer game as "a game that is carried out with the help of a computer program." This is a broad definition and includes games that are played on a personal computer, a video game console plugged in to a TV, and even small hand-held devices like cell phones. In order to situate the presentation I will start this paper with a historical summary of games in general. This is followed by the main section where I present five broad themes in current-day computer gaming and cartography. The presentation highlights some of the connections between these two dynamic fields and I argue that there are many areas of potential synergy to explore in the future.

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Historical Perspective

Games that incorporate maps go back as far as games have been played. Probably the most well known historical games that use a map is the family of chess games (Parlett 1999), but many other traditional games like draughts (checkers) and Go have their roots in real world scenario simulations where players assume the role of an army leader charged with the objective to overcome an enemy and conquer land. While these games, and chess in particular, are often referred to as the 'original' war games, many similar war strategy games are found much earlier in Indian and Chinese cultures (Michael and Chen 2005). They are all examples of

Figure 1.
Rambles playing board. Source: Library of Congress (*http://loc.gov/pictures/resource/pga.03272/*)

Axis & Allies miniature game. Source: Peter Kapitola, licensed under the Creative Commons Attribution-Share Alike 2.5 Generic license (*http://upload.wikimedia.org/wikipedia/commons/5/5d/Axis_%26_Allies_Map_%26_Pieces.jpg*)

'serious' war games that allowed players to gain useful insights into tactics and strategy using a birds-eye view of a battlefield.

One of the most important functions of a game map is the way it supports the game mechanics and rules. Many of these historical games employed very simple and abstract maps, often reducing the need for a realistic looking cartography to very basic and abstract topology of territories. Again, the traditional chess board is a prime example with its 8x8 square grid of positions and strict rules for movement of the different pieces. However, this pattern changed dramatically with the first incarnations of modern-day war games, or "Kriegspiel", developed in the early 1800's to simulate real warfare (Mathieu and Barreteau 2006). These war games and many of its followers incorporated real or realistic looking maps to enhance the game experience and they often employed the mapped geography to affect the game mechanics. More advanced war games were gradually developed and notable examples were those developed for the Prussian army where detailed topographic maps in a scale of 1:8,000 were used as the game board.

Soon after the introduction of modern war games, game maps in general underwent a radical change in the mid-19th century when advances in lithography and mass production techniques allowed games to be commercially printed in large quantities. This period also saw a broadening of game purposes, away from the previously narrow focus on practice and training in warfare. In the U.S. a large proportion of board games now focused on factual and educational goals in areas like history and geography (Whitehill 1999). One example is the 1881 game "RAMBLES Through Our Country" where players wind their way through the entire United States with the goal to get to the finish line (in New York City) first. The map is numbered to lead the players on the path towards the goal, with rich written geographic narratives of each place along the way, but the map also works as a standalone pictographic map of United States physical and cultural geography.

Another tendency was for game producers to tie a game to current and noteworthy events. For example, in 1891 the game Race Around the World capitalized on the travels by Elizabeth Cochrane Seamen, a.k.a. "Nellie Bly," who followed in the footsteps of fictional character Phileas Fogg to complete a trip around the world in 72 days (Avedon 2010). The well-publicized trip formed the basis for the game where two players race each other across a physiographic world map to complete the journey first. At this time there was a close connection between state-of-the-art cartography and game development. In fact, up until the early 1900's, many games were designed and produced by cartographers and existing publishers of maps and books (Goodfellow 1998). Now this has changed; most cartographers and geographic information professionals would look at 21st century cartography and game development as entirely separate fields. However, I argue that their trajectories over the last century or so have showed many striking similarities and connections that continue until this day. The following section is organized into five themes under which I elaborate on these connections in order to identify some yet unexploited linkages between current-day computer games and cartography.

The Connected Trajectories of Computer Games and Cartography

Two important factors during the first half of the 20th century have contributed to shape the development of computer based games and cartography alike: 1) the industrial-military complex emerged as a driving force behind developments of training and simulation tools, for example the first flight simulators developed during the 1920's, and 2) the introduction of computers in the 1950's revolutionized the development of these simulations by providing a radically new automation and calculation environment (Bergeron 2006).

Spatial analysis

It is clear that the introduction of computers have had a profound role in the development of modern cartography and GIS. The introduction of computers also coincided with the so-called "Quantitative Revolution", developments in spatial statistics, and the emergence of analytical cartography (Tobler 2000). Here we find many interesting parallels between these analytical perspectives on maps and the use of regular grids and topology in games. While not often thought of as a map, the regular chess board has, to GIS modelers and spatial analysts, a familiar grid layout. In fact, the use of Queen's case and Rook's case contiguity (O'Sullivan & Unwin 2003) in the teaching of spatial auto-correlation are only intuitive if a student is familiar with Chess. While tiled squares seem to have been the prevailing pattern for many traditional board games, there are many examples of hexagonal and even triangular tessellations (Parlett 1999). In many war games where the measurement of movement is an important factor, the hex map is commonly used because of its equal distance between all connecting grid cells. In addition, variations on the now popular Axis & Allies game include terrain-specific rules for troop movements across the game map, a direct parallel to cost surface analysis in GIS. As computer technology became publicly available, many of these regular games found their way into the digital realm, but it is unclear how much of spatial analytical theory that was built into algorithms to supported these games, or if any of the game specific developments ever provided input to for example analytical cartography.

Simulation, the Internet and Web 2.0

In 1977, the Atari 2600 became the first popular and widely adopted computer game console, and the simulation possibilities offered by its numerical processing capacity introduced a completely new type of simulation game to the larger public. In games such as Lunar Lander, Space Invaders, and Pong, there was a real-time interaction with elements of a simulated, virtual world. Around the 1980's, the military started to connect advanced flight simulators so that several trainees could interact in the same battle scene (Michael & Chen 2005). Game developers were soon to follow and provided increasingly sophisticated multi-player environments where participants could interact both as teams and as opponents, laying the foundation for increasingly social and participatory activities in computer games (Steinkuehler 2004). The growth of the Internet into the World Wide Web in the 1990's provided new opportunities for game developers and cartographers alike. Not only did it open up the potential for new types of digital distribution, but it also offered the option of many alternative modes of collaboration; from same-time, same-place, to different-time, different-place interactions, and combinations thereof (MacEachren 2000). This provision of telepresence offered by the Web created expanded options for multi-user interaction, for example multi-player gaming with remotely located players. At this point, the gaming community already had a large segment of user-driven development and was able to quickly leverage the Web for enhanced collaboration that continues to this day. Communities are often formed around particular games as a mix of both users and producers, and many participants actively practice both roles. A prominent example of these communities is the wiki devoted to the online game World of Warcraft (*www.wowpedia.org*), by some accounts claimed to be the second largest English-language wiki in the world behind Wikipedia. Another interesting example from these communities is the annual Ennie award for Best Cartography (*http://www.ennie-awards.com*) where game maps for tabletop role-playing games have been competing since 2001 for recognition as the individual product containing the best art or technique of making maps or charts.

In contrast, academics in cartography and GIS struggled during the early years of the Web with substantial critiques against the notion that the new technologies suffered from reinforced positivist thinking reminiscent of the quantitative revolution, a lack of inclusiveness, and that it served as a tool to enforce power and surveillance (Curry 1997; Pickles 1995). Influenced by these critiques, public participatory GIS, or PPGIS, emerged as a foundation for a broader public to express multiple perspectives in mapping and spatial discourse (Sieber 2006). Despite significant activity and growth of public participatory mapping, technical and software limitations remained hurdles for a broad uptake of bottom-up, community driven mapping. This would change, however, as Google, Microsoft, and Yahoo established themselves as general reference map publishers on the Internet. In 2005 their release of free and open Application Programming Interfaces (APIs), allowed users to create their own maps, enabling the growth of online co-creation of geodata, online mapping, and new ways for communities to share geospatial information. More recently, sites like GeoCommons and Ushahidi have provided additional platforms for community driven map-making, as evidenced during recent crises surrounding the earthquakes in Haiti and Japan (Zook, Graham, Shelton and Gorman 2010). In addition, user forums and software websites now enable discussion and sharing of cartographic ideas and tools. Despite this progress, the web still offers cartographers room for even richer and more active conversations around design ideas, sharing of novel tools, and collaborative development. Game developer communities provide an excellent source for inspiration in these practices.

Increased realism and virtual worlds

Traditionally a map is defined as either a tangible print or a virtual product that depict the cultural or physical environment (Dent 2009), or a milieu including mental abstractions of a geographic landscape (Robinson 1996). Many table-top role-playing games initially built on the tradition of war games with the map and game pieces as abstractions of the real world and army units. In the 1970's however, the release of Dungeons & Dragons added a new dimension to these games by shifting focus from controlling entire armies down to individual characters (Cover 2010). Part of this shift was also a greater emphasis on a rich narrative, often based on fantasy or science fiction. With increasing processing power, computer games could pick up on this trend and produce games with increased level of detail and a focus on controlling an individual character that navigates a virtual world. When it comes to design and development of virtual worlds, current day game engines provide high-end computer graphics at relatively low cost. As game maps and geospatial visualization have grown increasingly less abstract - with high-resolution graphics, virtual reality and augmented reality - separate data standards have emerged that cater to the particular needs of each technique. Unfortunately, incompatible formats have created obstacles for interoperability and exchange of technologies between gaming and GIS cartography. Similar to modern-day cartographers, game developers commonly use general-purpose graphic design software for the design of game maps and virtual worlds. The standard file formats for these graphics, models, and images are largely determined by the most popular 2D or 3D authoring tools, such as 3ds max, Maya, and Softimage XSI. In the geospatial world, a whole different set of standards have evolved from remote sensing, GIS technologies, and the launch of virtual

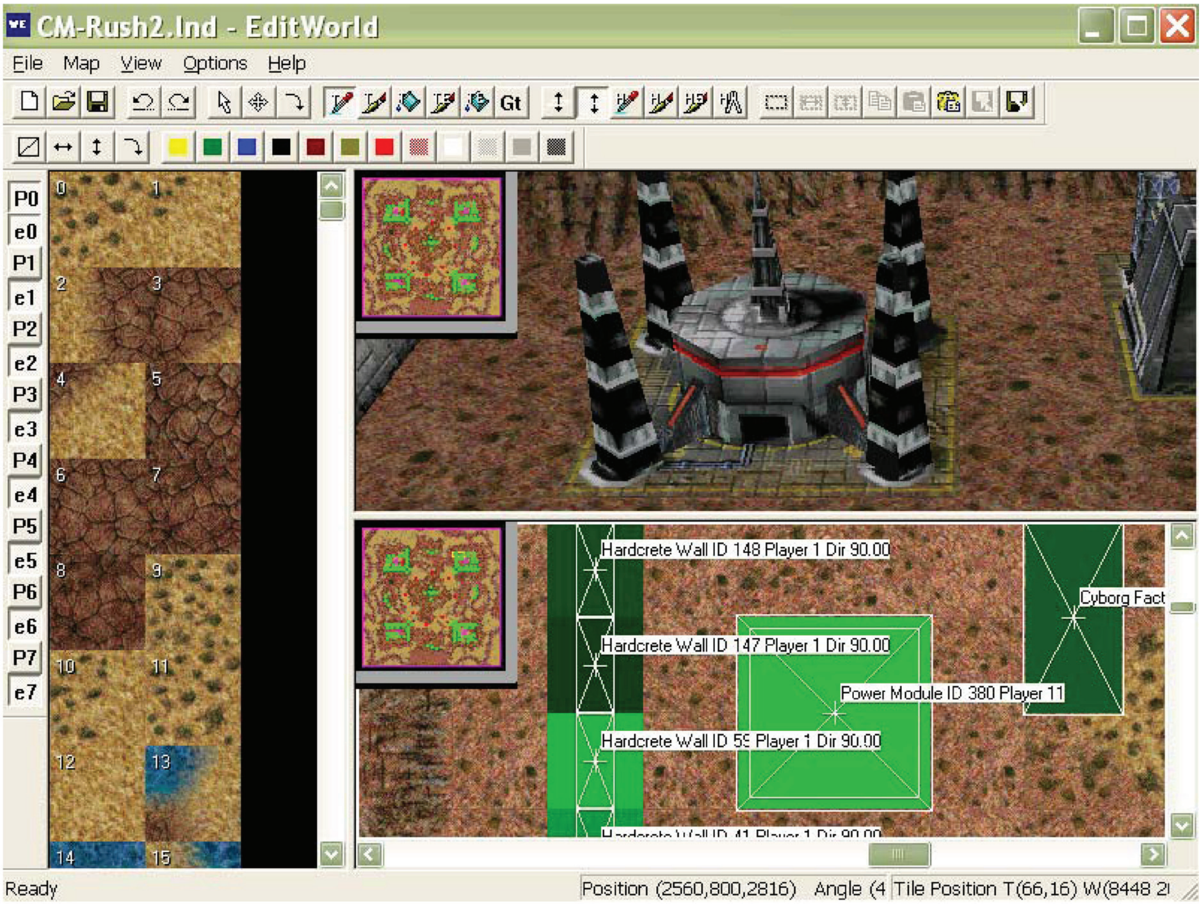

Figure 2. Example level editor for the game Warzone 2100, an open source real-time strategy game. Source: Wikimedia Commons, screenshot of user interface of software under GNU General Public License.

globes with high resolution aerial imagery. In addition, game engines rarely use any of the native formats of graphic authoring tools. As a result, interoperability between mapping/gaming and design software has depended on common exchange formats and reliable import/export functionality in either software. As an example, Oleggini et al. (2009) demonstrated the possibility to import NASA Shuttle Radar Topography Mission (SRTM) elevation data elevation data into a real-time-rendering game-engine to obtain an immersive 3D cartographic virtual environment. Their study also illustrated some performance issues related to the need for variable resolution data and real time rendering at more than 30 frames per second. Similar issues were found in a study by Herwig, Kretzler and Paar (2005). The development of better interoperability between gaming data formats and GIS is desirable in the future.

Designed worlds

Game maps and virtual worlds are often entirely made up and even surrealistic. Still, game designers often use the real geography as a starting point, but when it imposes unwanted limitations or benefits for the game dynamics, game-map designers often modify or re-create reality to fit the specific game dynamics. For example, in the popular game Diplomacy, Agar (1992) recommends map designers to modify the topology (connectivity) of territories to ensure that the players (powers) have at least three or more directions in which they can expand. This modeling approach to game-map design is often equally concerned about the function of objects in the game as it is with appearance and aesthetics. Thus, many game-map design environments have strongly typed map elements where the object type, for example a road, also comes with a specific visual appearance and game-specific functions (a smooth path where cars and other vehicles can move easily). An example game-world editor is shown in Figure 2 where the three main windows contain a) the available surface types with specific visual and function-oriented properties, b) a 3-D rendering of the game-world, c) orthogonal map view of the game-world.

Recent releases of many popular games now contain rather powerful map editors that allow users to design their own game worlds using a graphic user interface similar to the more advanced, general-purpose 3D design environments mentioned above.

Few cartographic texts have elaborated on maps and map-making that have entirely imaginary worlds as their primary object. Despite an early recognition of the potential benefits of a more design-oriented cartography in the analytical cartography literature (Moellering 1980; Nyerges 1991), digital modeling of existing landscapes for scenario-building is mostly found in the landscape architecture and environmental planning literature (Bishop and Lange 2005; Ervin 2001). Sheppard (2005) for example argued that visual communication, especially realistic landscape visualizations, could help in advancing peoples' understanding of the impacts of for example climate change scenarios. Still, most of this work is done with existing GIS and geospatial data bases where the modeling capabilities are limited.

A cartographic work-flow usually starts with already existing spatial features and creates visual abstractions of these to be added to a map, while the design process often starts with an abstract notion of what a milieu should look like. A closer connection of geospatial technology with a design process is envisioned by the concept of GeoDesign, attributed in large part to Carl Steinitz at Harvard University, (Dangermond 2009). The GeoDesign framework includes at least four elements; Sketching of potential plans and designs, Spatial models that can simulate impacts of proposed designs, Rapid feedback on the effects of any proposed/sketched design, and Iteration through several alternative designs (Koncz 2010). While a combination of cartographic, GIS, and design software would have the potential to deliver most if not all of that functionality, it is interesting to note that game software already have integrated all four of these elements. The game-map editors with typed libraries of objects support the sketching and spatial modeling of elements, constructed maps can immediately be tested by players and provide rapid feedback on any suggested edits, and alternative worlds can easily be saved and tested separately to allow for iteration through alternative designs. Adding to this, current game platforms also support massive multi-user functionality that can open for public participatory approaches, and the support for artificial intelligence could allow for highly sophisticated simulations and landscape visualizations.

Content standards and data semantics

As game maps and virtual worlds have grown larger and more complex with more and more people involved, an important task in game development is keeping track of the assets in a game. Assets are essentially any components that are used by the game such as sound, special effects, graphic art textures, terrain, and much more. These assets are collected in various libraries and thus needs some indexing for organizational purposes. Naming conventions have become a critical feature of an asset catalog (Bergeron 2006) and game developers increasingly refer to controlled vocabularies or thesauri developed by professional organizations or standardization institutes, for example the NASA Thesaurus, the National Library of Medicine's MeSH controlled vocabulary, and the Art and Architecture Thesaurus (AAT). The strict typing of assets has also facilitated the development of modifiable game assets so that user communities can contribute to these collections. Similar needs have driven cartographers to develop controlled vocabularies and ontologies, for example the recent development of ontology for The National Map (Varanka 2009). The increasing support for typed asset libraries based on standard ontologies facilitates the translation from, say an ontology-based National Map and Geographic Style Sheets (GSS) into a gaming engine for interactive visualization. A prime example of this approach was demonstrated by Warren (2009) who developed and applied a GSS in the style of the game Warcraft 2 to the entire

OpenStreetmap database which in an instance rendered the entire world in the graphic style of this particular game. Obviously the reverse process, from simulated map data to a familiar set of cartographic styles, would be as feasible.

Conclusion

In this report I began by providing a historical review of the connections between games and cartography. I then highlighted several, yet uncharted, connections between computer gaming and cartography over the past few decades. Most of these are related to the influence of rapidly evolving computing technology and the provisions offered by the Internet. Within this short overview it has not been possible to highlight all connections between games and cartography, nor to expand on all of the actual exchanges and flows of ideas, approaches, and technologies between the two. Still, I argue that the convergence of examples of multi-user environments, virtual and simulated worlds, design approaches, and increased need for and work with standardization suggests potentials for a collaborative future with a continued and closer co-evolution around these and other emerging themes. We begin to see a fruitful exchange of ideas, technologies, and practices between gaming and cartographic communities. One example of such efforts is the Neverwinter Nights in Antarctica game developed by Dormann et al. (2006) where they examine the potential for a computer based role-playing game to support critical thinking by presenting multiple points of view. Another example is the GeoGame Green Revolution game (Ahlqvist et al. 2009) that used GIS and multi-player online gaming technology to give geography students an immersive experience of being a farmer in India. Both examples clearly illustrate the potential of combining modern cartographic theory, tools, and practice with gaming approaches. Yet much of this potential remains largely untouched by cartographers, landscape designers, and GIS professionals. My hope is that this overview will inspire more exploration in the years to come.

REFERENCES

Agar, S. 1992. *Designing Maps for Diplomacy Variants*. The Variant Bank. Online: *http://www.variant-bank.org/articles/designing_maps.htm* (accessed 26 September 2010).

Ahlqvist, O., T. Loffing, J. Ramanathan and A. Kocher. 2009). *Virtual globe games for participatory GIS*. Poster presented at the International Cartographic Conference, Santiago, Chile: ICC.

Avedon, E. 2010. *Race Around The World Game*. Elliott Avedon virtual museum of games. Online: *http://www.gamesmuseum.uwaterloo.ca/VirtualExhibits/Map%20Games/racearound/index.html* (accessed 28 September 2010).

Bergeron, B. 2006. *Developing Serious Games. ProQuest Tech Books*. Course Technology PTR. Online: *http://proquest.safaribooksonline.com/9781584504443*.

Bishop, I. D. and E. Lange. 2005. *Visualization in Landscape and Environmental Planning: Technology and Applications*. London and New York: Taylor & Francis.

Cover, J. G. 2010. *Creation of Narrative in Table-top Role-Playing Games*. Jefferson, NC, USA: McFarland & Company, Inc., Publishers.

Curry, M. R. 1997. The Digital Individual and the Private Realm. *Annals of the Association of American Geographers* 87(4): 681-699.

Dangermond, J. 2009. GIS: Designing Our Future. *ArcNews* Summer: 6-7.

Dent, B. D. 2009. *Cartography: Thematic Map Design (6th ed.)*. New York: McGraw-Hill Higher Education.

Dormann, C., A. Caquard, B.A. Woods and R. Biddle. 2006. Role-playing games in cybercartography: multiple perspectives and critical thinking. *Cartographica* 41(1): 47-58.

Ervin, S. M. 2001. Digital landscape modeling and visualization: a research agenda. *Landscape and Urban Planning* 54(1-4): 49-62.

Goodfellow, C. 1998. The Development of the English Board Game, 1770-1850. *International Journal for the Study of Board Games* 1: 70-80.

Herwig, A., E. Kretzler and P. Paar. 2005. Using games software for interactive landscape visualization. In I. D. Bishop and E. Lange (eds.), *Visualization in landscape and environmental planning: technology and applications*. London and New York: Taylor & Francis.

Koncz, J. 2010. Making Smart Growth Smarter with GeoDesign. *Directions Magazine*. Online: *http://www.directionsmag.com/articles/making-smart-growth-smarter-with-geodesign/122336* (accessed on 28 September 2010).

MacEachren. 2000. Cartography and GIS: facilitating collaboration. *Progress in Human Geography* 24(3): 445-456.

Mathieu, D. and O. Barreteau. 2006. *I. Survey on past experiences and practices on the use of roleplaying games in the field of water management & II. Proposal for a common framework* (Project deliverable No. FP6 - 511231) (p. 35). AQUASTRESS Consortium. Online: *http://www.aquastress.net/share/img_deliverables_file/20_1_Aquastress_WP5.3-D5.3.-1.pdf*

Michael, D.R. and S.L. Chen. 2005. *Serious Games: Games that Educate, Train, and Inform*. Boston, Mass.: Thomson Course Technology.

Moellering, H. 1980. Strategies of Real-time Cartography. *The Cartographic Journal* 17(1): 12-15.

Nyerges, T. L. 1991. Geographic information abstractions: conceptual clarity for geographic modeling. *Environment and Planning A* 23: 1483-1499.

Oleggini, L., S. Nova and L. Hurni. 2009. 3D Gaming and Cartography-Design Considerations for game-based generation of Virtual Terrain Environments. In: *Proceedings of the 24th International Cartographic Conference*. Santiago, Chile: ICC.

O'Sullivan, D. and D.J. Unwin. 2003. *Geographic Information Analysis.* Wiley Hoboken, NJ.

Parlett, D. S. 1999. *The Oxford History of Board Games*. Oxford: Oxford University Press.

Pickles, J. 1995. *Ground Truth: The Social Implications of Geographic Information Systems.* The Guilford Press.

Robinson, A. H. 1996. *Elements of Cartography (Vol. 6)*. New York: John Wiley & Sons.

Sheppard, S. R. 2005. Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. *Environmental Science & Policy* 8(6): 637-654.

Sieber, R. 2006. Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers* 96(3): 491-507.

Smed, J., and J. Hakonen. 2003. *Towards a definition of a computer game (No. 553). TUCS Technical Report*. Turku, Finland: Turku Centre for Computer Science.

Steinkuehler, C. A. 2004. Learning in massively multiplayer online games. In: *Proceedings of the 6th International Conference on Learning Sciences*, pp. 521-528.

Tobler, W. 2000. The Development of Analytical Cartography: A Personal Note. *Cartography and Geographic Information Science* 27(3): 189-194.

Varanka, D. 2009. Landscape Features, Standards, and Semantics in U.S. National Topographic Mapping Databases. In: S. Dragicevic, D. Roman, & V. Tanasescu (eds.), *Advanced Geographic Information Systems & Web Services, GEOWS 2009,* pp. 152-157. Los Alamitos, Californina: IEEE Computer Society.

Warren, J. 2009. *ICCM 2009 - Cartagen and SMS Mapping - Crisis Mappers Net*. Presented at the first International Conference on Crisis Mapping (ICCM 2009), Cleveland, Ohio. Online: *http://crisismapping.ning.com/video/iccm-2009-cartagen-and-sms.*

Whitehill, B. 1999. American Games: a historical perspective. *International Journal for the Study of Board Games* 2: 116-141.

Zook, M., M. Graham, T. Shelton and S. Gorman. 2010. Volunteered Geographic Information and Crowdsourcing Disaster Relief: A Case Study of the Haitian Earthquake. *World Medical & Health Policy* 2(2): 9-33.

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GIS and Geoenabled Cartography

Howard Veregin

There is nothing new about the idea of using GIS to make maps. But over the last decade there has been a dramatic increase in the ability to produce high-quality cartographic output using end-to-end GIS-based workflows. A commercial example is the 22nd edition of Rand McNally's Goode's World Atlas (Veregin, 2010), for which the world reference map series was produced entirely with commercial GIS software. To cite another example, the winner of the 2010 Esri Special Achievement in GIS award for cartography was Mapping Specialists, a Wisconsin mapping company, for their new US road atlas created from a seamless nationwide GIS database ("2010 SAG Award Winners," 2011). At a national level, the US Geological Survey is creating its new nationwide US Topo map series ("Topographic Maps for the Nation," 2011) using a seamless database and a GIS-based workflow that incorporates automated procedures costing a fraction of comparable manual methods. In these cases and others, cartographic production facilities are recognizing that modern GIS software offers numerous advantages over traditional methods, including production efficiency, relative ease of maintenance, and enhanced flexibility to reuse and repurpose components of the cartographic production process.

I use the term *geoenabled cartography* to identify the cartographic production model that relies on GIS as the underlying data source, processing platform, and map rendering engine (Veregin, 2009). Geoenabled cartography has three essential elements, (a) an underlying set of richly attributed geospatial data, (b) the use of automated procedures to manipulate and process these data, and (c) the ability to store, reuse, modify and leverage these procedures in other contexts. According to this model, cartographic symbolization is achieved through interactions between data and procedures, thus eliminating the need for interactive editing to generate map symbology. These procedures can be common GIS tools but also encompass complex methods that focus on labor-intensive components of the map production process, including feature selection and generalization, label placement, and map rendering and output. The ability to store and reuse these procedures – using scripts or rulebases – allows them to be reused and adapted to different purposes, which promotes efficient leveraging of the initial investment.

Despite the advantages offered by this model, there is lingering resistance on the part of many professional cartographers to the idea of employing GIS as the primary tool for map making. As Director of GIS Operations at Rand McNally (prior to my appointment as Wisconsin State Cartographer) I helped develop and implement new GIS-based workflows for the company's print map products. These efforts were sometimes challenged by cartographers who viewed the new technology as clumsy and inefficient compared to the desktop illustration software widely used for cartographic production purposes. Another challenge resulted from conceptual roadblocks that limited the ability of some cartographers to easily adapt to new GIS-based workflows, especially when these workflows eliminated or rearranged the specialized silos associated with more traditional cartographic production tasks.

Many cartographic production facilities, partly due to tradition and partly due to software limitations, tend to view the production of a physical map (or map series) as cartography's *raison d'etre*. Geoenabled cartography, instead, focuses on creating cartographic capability – in

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other words on creating a specific implementation of cartographic data, procedures, and rules to support a specific mapping objective. Any physical maps that result are in a sense byproducts of this implementation. A particular map is just one of many possible representations of the data, and other representations are easily created by modifying how procedures are applied. Since maps are byproducts of the process rather than the objects of that process, individual maps become less intrinsically valuable, and in some cases even disposable. The traditional emphasis on a single map as the culmination of the cartographic process is out of synch with technology that allows alternate maps to be generated so easily.

Geoenabled cartography offers a precise and unambiguous way to define map specifications, since cartographic data and procedures are explicit. A map is – quite literally – an enumerated set of procedures operating in a specific sequence on a stored geospatial database. Details on processing steps and their sequence can be communicated to others, often in the form of a script, which can then be reused or adapted for different purposes. Within a single organization, such as a mapping company, this can offer significant efficiencies by leveraging the initial development effort and investment. When it occurs across organizations, as when a script is shared on a Web forum, cartographic methods are disseminated to a broader group, thus enhancing the potential for evolution and adaptation. One might argue that this formal map specification is more important than any physical maps that result from it. In any case the ability to expose and share the data and procedural elements of a given map is something no paper map – even one produced with desktop illustration software – can easily do.

This latter point is rather important. With desktop illustration software, cartographers use their skills to create specific maps, pouring their knowledge, experience and energy into individual products and making interactive edits to generate symbology. This approach is fundamentally an artisanal one, as it relies on hand craftsmanship and delivers products that are unique, individual, and not always reproducible. While some procedures can be implemented as scripts or otherwise replicated by others, in general the only model of the map production process is the final map itself. The data and procedures used to create the map are rolled up inside it without an easy way to extract them, reuse them, or learn from them. While there are certainly merits to artisanal cartography, it is surprising that this production model has existed so long in commercial map publishing given its implications for production costs and product consistency.

Beyond the commercial advantages, geoenabled cartography also supports the Web-based mapping applications that have generated so much interest over the last few years. Strictly speaking, many of these applications do not use GIS software *per se*. Still, many of the data processing and map rendering methods that they use are derived from standard GIS tools. Furthermore, the applications themselves reflect the core idea of geoenabled cartography: the use of stored, repeatable procedures applied to underlying geospatial data. In particular, the ability to customize the map display as a function of user interaction is an example of rule-driven symbology supporting highly customized on-the-fly map renderings tailored to specific user requirements. This capability has made the Web a liberating force for cartography and the spatial sciences. Literally thousands of non-professional cartographers have been able to develop innovative representations of datasets to support their interests, research efforts and professional activities. In the humanities and other traditionally aspatial disciplines this phenomenon has contributed to a "spatial turn" that includes wider acceptance and adoption of maps in scholarly research.

I argue that the roots of geoenabled cartography lie within Waldo Tobler's paradigm of analytical cartography. Tobler developed the first course in analytical cartography at the University of Michigan in the late 1960s. He viewed cartography as a means to examine and solve geographical problems and to develop and refine geographical theory (Tobler, 2000, 189). As such analytical cartography was based on a foundation of mathematical theory, which set it apart from traditional cartography with its emphasis on the communicative and artistic aspects of map design (Moellering, 2000a, 187). Much of the subject matter of analytical cartography – projections, transformations, topology, data models, generalization, spatial interpolation, spatial filtering, dynamic mapping, numerical map analysis, and so on – has subsequently become tightly integrated into GIS (Clarke and Cloud, 2000, 195). Today these methods make geoenabled cartography possible by facilitating the manipulation, transformation, and analysis of geospatial data. Like analytical cartography, geoenabled cartography is focused on utilizing the power of data/method interactions to drive the mapping process, and emphasizes the importance of often highly customized maps that meet specific user needs. There are also parallels with geovisualization (Kraak & MacEachren, 1999) which emphasizes interactivity and user-centric customization, data analysis to support exploration and hypothesis testing, and multiple (often simultaneous) visualizations. Like geoenabled cartography, geovisualization also recognizes the inherent limitations of traditional static maps.

I believe it is time to refocus energy on the tools of analytical cartography that give geoenabled cartography its power. Several areas in particular require additional research and development, including automated feature generalization and label placement. Sophisticated tools have been developed for these tasks, but significant manual effort is often still required at the post-processing phase to ensure that maps are of acceptable quality. Further development of these tools would bolster the economic benefits of geoenabled cartography for map production and enhance the ability of Web-mapping applications to generate customized map renderings supporting specific user needs. Ultimately, it is these capabilities that will allow cartography to evolve in ways that better suit the needs of scientific and non-professional users, and to adapt to technological changes that are now just over the horizon.

REFERENCES

2010 SAG Award Winners. n.d. Online: *https://events.esri.com/uc/2010/sag/list* (accessed March 2011)

Clarke, K. C. and J. G. Cloud. 2000. On the origins of analytical cartography. *Cartography and Geographic Information Science* 27(3): 195-204.

Kraak, M.-J. and A. M. MacEachren. 1999. Visualization for exploration of spatial data. *International Journal of Geographical Information Science* 13(4): 285-287.

Moellering, H. 2000. The nature of analytical cartography: An introduction. *Cartography and Geographic Information Science* 27(3): 187-88.

Tobler, W. 1976. Analytical cartography. *The American Cartographer* 3(1): 21-31.

Tobler, W. 2000. The development of analytical cartography: A personal note. *Cartography and Geographic Information Science* 27(3): 189-94.

Topographic Maps for the Nation. n.d. Online: *http://nationalmap.gov/ustopo/TopoMapBroch_New5.pdf* (accessed March 2011)

Veregin, H. 2009. *Geoenabled Cartography.* Keynote address, GIS Day, University of Wisconsin - Milwaukee.

Veregin, H. (ed.). 2010. *Goode's World Atlas, 22nd Edition*. Skokie, Illinois: Rand McNally & Co.

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Adapting Generalization Tools to Physiographic Diversity for the United States National Hydrography Dataset

Barbara P. Buttenfield, Lawrence V. Stanislawski and Cynthia A. Brewer

Abstract: This paper reports on generalization and data modeling to create reduced scale versions of the National Hydrographic Dataset (NHD) for dissemination through *The National Map*, the primary data delivery portal for USGS. Our approach distinguishes local differences in physiographic factors, to demonstrate that knowledge about varying terrain (mountainous, hilly or flat) and varying climate (dry or humid) can support decisions about algorithms, parameters, and processing sequences to create generalized, smaller scale data versions which preserve distinct hydrographic patterns in these regions. We work with multiple subbasins of the NHD that provide a range of terrain and climate characteristics. Specifically tailored generalization sequences are used to create simplified versions of the high resolution data, which was compiled for 1:24,000 scale mapping. Results are evaluated cartographically and metrically against a medium resolution benchmark version compiled for 1:100,000, developing coefficients of linear and areal correspondence.

Keywords: differential generalization, multiple representations, MRDB, hydrography, metric assessment, coefficient of line correspondence

Introduction

Common objectives for cartographic generalization include preservation of cartographic and geographic logic. Cartographic logic refers to the condition that the smaller scale data version retains levels of detail which meet visual expectations. Essentially this means that the simplified data "looks right" in the context of other map information. Geographic logic is retained when generalized data versions reflect evidence of their site and situation in the landscape. For example, a smaller scale representation of an arid landscape must preserve ephemeral stream characteristics such as channel discontinuity and the presence of playas and washes. A depositional coastline processed for smaller scales should preserve the regular periodicity and scalloped character of barrier beaches. Generalization processing to meet these objectives often involves modifying data geometry, symbolization, or both. Satisfactory results can be achieved for data spanning small scales or example landscapes with uniform characteristics, as evidenced in example illustrations found in many American cartographic textbooks (Slocum et al. 2009; Dent 1999; Robinson et al. 1995). Larger regions with diversified landscape characteristics present more of a challenge for a national mapping agency such as the United States Geological Survey (USGS) in developing a generalization strategy.

The premise of this research is that a single automated generalization sequence with uniform tolerance parameters cannot create adequate reduced scale representations in all types of heterogeneous landscapes encountered across the United States. There are important implications in this approach for data production and for cartographic design at multiple scales.

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Automated generalization processing and data modeling will reduce workloads and improve consistency of results, but may require special expertise. Some data layers (terrain and hydrography) are more sensitive to scale change than others (transportation and settlement) and must be generalized at more frequent scale intervals to produce useful data products and readable maps. Analytical uses of reduced scale data carry additional needs and requirements, to support reliable data measurements, and to ensure that features integrate horizontally (within layers) as well as vertically (between layers) (Bobzien et al. 2008; Buttenfield and Frye 2006; Spaccapietria et al. 2000). Consistent data modeling mandates metric assessment of generalized data versions, to ensure reliability of measured geometric characteristics at all levels of resolution.

This paper reports on generalization and data modeling to create reduced scale versions of hydrographic data for *The National Map* (*http://nationalmap.gov*) of the USGS. The work draws upon several years of stepwise efforts by the authors to estimate upstream drainage area (UDA) for every stream reach between confluences (Stanislawski et al. 2007), to automate stream pruning on the basis of local density (Stanislawski 2009), to quantify reliability of generalization results (Stanislawski et al. 2010a; Buttenfield et al. 2010), as well as for visual evaluation of mapped hydrography (Brewer et al. 2009). The paper demonstrates that generalization processing can be varied to preserve local or regional differences in hydrographic characteristics that reflect natural variations in landscape type. Specifically tailored processing sequences generalize data compiled for the National Hydrography Dataset (NHD) at 1:24,000 (24K) scale. Results are evaluated metrically against benchmark NHD data compiled for 1:100,000 (100K) scale subbasins. Terminology and concepts common to United States hydrographic data such as flowlines, reaches, and subbasins may be reviewed at the NHD website (*http://nhd.usgs.gov/documentation.html*), with a particularly helpful overview in the chapter called *Concepts and Content* (*http://nhd.usgs.gov/chapter1/chp1_data_users_guide.pdf*).

Hydrographic data is chosen for a number of reasons. It comprises the vector data layer most sensitive to changing spatial resolution. It is characterized by having the most stringent requirements for vertical integration with terrain, so that streams run along valley bottoms and not up the sides of ridges for example. As such, hydrography is expected to manifest the most difficult data modeling problems in generalizing vector data. In addition, hydrography is commonly utilized in topographic base mapping at every scale, and will be in high demand by users of *The National Map*.

Establishing a Reliable Physiographic Context

The United States is large, and comprises diverse physiographic regions (Figure 1a). Initial results by the authors of this paper (Buttenfield et al. 2010; Stanislawski et al. 2009; Brewer et al. 2009) led to the argument proposed here that landscape differences which reflect local physiography and local climate require differing generalization sequences for effective multiscale representation. The traditional resource cited for defining United States physiographic regions is Fenneman and Johnson (1946), whose divisions were created manually and at a relatively coarse resolution. Relying solely on the Fenneman and Johnson physiographic divisions however does not reflect enough spatial variability at the subbasin level to model realistic transitions for generalization strategies across the range of conditions in the country. Consequently, alternative landscape delineation approaches are needed for hydrographic generalization of the United States.

Touya and others (Touya 2008; Touya et al. 2010) have proposed an implementation of context-specific processing applied to subjectively determined urban landscape delineations. Their solution is based on terrain and transportation characteristics. Other research has been completed on automatic delineation of landscape partitions with specific characteristics, to help orchestrate choices among a set of automated generalization operations for large and/or varied datasets (van Oosterom and Schenkelaars 1995; Bobzien et al. 2008; Chaudhry and Mackaness 2008a, 2008b; Fathi and Krumm 2010). Progress in multiscale morphometric approaches are also reviewed by Deng (2008) with an emphasis on environmental modeling goals. But none of these approaches can account comprehensively for the wide range of terrain and climate conditions within the United States, which form diverse hydrographic conditions.

Chaudhry and Mackaness (2008c) apply morphometric analysis to build extents of mountain ranges from individual peak locations. Their objective is to derive "morphostructural regions" suited to smaller scale mapping. Multiscale morphometric analysis approaches typically encompass landscape variation across distances ranging from tens of meters to approximately one kilometer (e.g., Schmidt and Andrew 2005) and with differences resulting from focal windows ranging from 3x3 pixels to 75x75 pixels (which covers 3,700 ground meters at the working scale of Fisher et al. 2004). In these contexts, scale change refers to DEM resolution change, but is still focused on automatic identification of parts of landscapes such as peaks, ridges, passes, plains, channels, and pits (Wood 1996). This level of detail is much finer than the subbasin-based approach applied in this paper, and much too fine to process hydrography for the entire United States in a manageable way. The aim in this research is not, for example, to differentially generalize the opposing sides of every ridge and valley in the United States at the resolution of individual formations. Such a data processing task could not be completed within a reasonable update cycle.

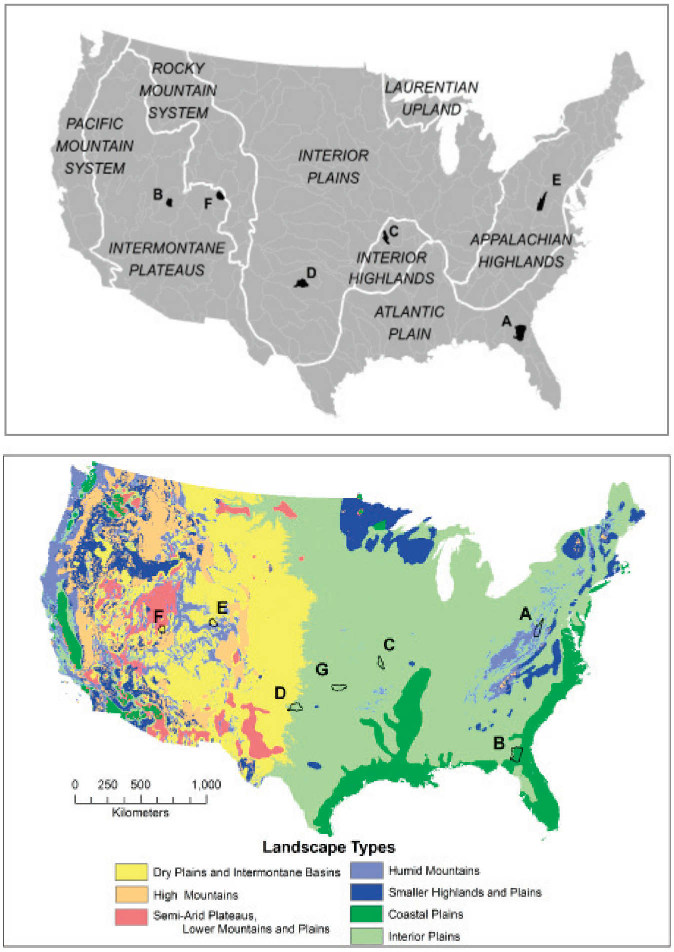


Figure 1 (a) top (b) bottom. Two physiographic taxonomies. (a) a widely adopted but subjective categorization (Fenneman and Johnson 1946); (b) results from statistical clustering of seven terrain and hydrographic variables (Stanislawski et al. 2010). National Hydrography Dataset (NHD) subregions are overlain on the classification. Letters identify NHD subbasins processed to date to verify the premise that generalization must be tailored to landscape type.

Regional classification based on hydrography remains a challenging problem, because water channels are quite sensitive to terrain roughness, precipitation and other factors (Carlston 1963; Montgomery and Deitrich 1989; Tarboton et al. 1991; Tucker and Bras 1998). The premise of the research reported here is that differences in hydrographic pattern cannot be preserved across all variations evident in the national landscape using a single uniform processing sequence. Tailoring individualized generalization sequences to each subbasin would be unmanageable, of course. The middle path is to establish a set of terrain and climate characteristics that reflect the primary hydrographic patterns, and use these to regionalize the national landscape. Generalization sequences can then be tailored to the regions, and applied where landscape conditions are appropriate.

Stanislawski et al. (2011) classified the conterminous United States based on terrain and climate factors related to surface hydrography (Figure 1) in an effort to specify distinct landscape regions more formally than Fenneman and Johnson (1946), and to automate the identification of distinct landscape regions in each of which a unique hydrographic generalization approach could be applied.

The long term goal is to establish the smallest number of unique processing sequences which can fully accommodate the variety of available landscape types. The present paper discusses five subbasin examples, explaining and distinguishing the processing sequences and metric evaluation.

The classification by Stanislawski et al. (2010b) is based on seven environmental factors that influence surface hydrography. Three terrain factors, elevation, standard deviation of elevation, and slope, are averaged for each 5 km cell of a grid superimposed on USGS 1:250,000 scale 3-arc second digital elevation models (that is, DEMs with approximately 90m resolution). The latter two measures provide estimates of topographic surface roughness (Grohmann et al. 2009), which are similar to relief values used for terrain partitioning by Chaudhry and Mackaness (2008b). Two hydrographic factors include runoff (mm/year) based on a water balance model (Wolock and McCabe 1999), and drainage density estimated from high resolution (HR) NHD catchments (Stanislawski et al. 2007). (A catchment is a drainage basin where surface water flow converges to a single point, called the pour point, where the water flows out of the basin, is lost underground, or flows into another water feature such as another channel, a lake, reservoir or in coastal areas an estuary.) A third hydrographic factor is inland surface water, estimated from 100K medium resolution (MR) NHD polygons. Lastly, a bedrock density factor estimated for generalized geologic unit polygons (Reed and Bush 2005) was included. The seven factors were normalized and evaluated using a maximum likelihood classification, to generate a set of seven physiographic categories that are overlaid on the NHD subbasins (Figure 1b). In combination with the research presented here, future work will model generalization procedures (operation sequence and parameters) for each subbasin to blend procedures established for each associated landscape class and thus form adequate transitions along class boundaries.

In initial attempts to establish unique generalization sequences adapted to a range of landscape types in the coterminous United States as evidenced by the statistical clustering, a sample of NHD subbasins was selected, characterized by three terrain regimes (flat, hilly or mountainous), and by two precipitation regimes (dry or humid) (Table 1). Separate procedures have been developed for these six subbasins, some of which are described in the following sections.

Processing Methods and Approach

Generalization processing of the HR NHD is computationally intense and produces intermediate scale hydrographic datasets, called Level of Detail (LoD) databases (Cecconi et al. 2002) that retain the full NHD data structure, including name, feature type, and identifiers unique to each stream reach. The first set of LoDs is intended for mapping scales ranging from 1:50,000 (50K) to about 1:200,000 (200K) and referred to hereafter as 50K LoDs. Data modeling involves four stages of processing explained below. Methods to generate a 50K LoD are described while focusing on the Missouri subbasin (C). This subbasin forms the watershed for the Pomme de Terre River, Missouri. The subbasin sits in the Ozark Plateau of the Interior Highlands, and covers ~2,190 km2. The geography of this landscape is a humid climate with hilly but not mountainous terrain. Subbasin G, with characteristics similar to subbasin C, is used for validation. Subbasins B and D will be discussed briefly to demonstrate that landscape variations across our

Table 1. NHD subbasins used in this research. Processing for subbasins **B**, **C**, and **D** illustrates discussion throughout this paper; and subbasin **G** will be used to discuss metric validation.

Subbasin Name and Location	*NHD Subbasin*	*Regime*
A South Branch Potoma River, West Virginia	02070001	Humid Mountainous
B Upper Suwannee River, Florida-Georgia	03110201	Humid Flat
C Pomme De Terre River, Missouri	10290107	Humid Hilly
D Lower Prairie Dog Town Fork, Red River, Texas	11120105	Dry Hilly
E Piceance-Yellow Creeks, Colorado	14050006	Dry Mountainous
F Lower Beaver River, Utah	16030008	Dry Flat
G Lower Cimarron River, Oklahoma	11050003	Humid Flat

broad categories mandate differing emphases in automated generalization.

Enrichment

Enrichment adds attributes which support subsequent processing in several ways, e.g., to estimate local density values for each stream reach and to guide pruning. A stream reach in the NHD is a segment of surface water with similar characteristics that is assigned a permanent unique reach address, called a reach code, which serves as a mechanism for linking other data to the NHD (USGS 2000). Reaches are defined for non-overlapping confluence-to-confluence segments on the flowline network of the NHD. The attribute table of the hydrographic flowline network is enriched with estimates of catchment area, UDA, flowline density partition and channel hierarchy for each reach. Because the HR NHD does not include measured UDA values, they must be estimated for each feature in the hydrographic network (Stanislawski 2009). UDA estimates permit relative prominence ranking of stream reaches, which assists automatic centerline delineation (especially in braided flows) as well as tapering channel hierarchy symbols for cartographic display.

Pruning

Pruning eliminates entire reaches without damaging correct topology of the stream network, terminating when the summed length of remaining reaches approach a limit established by a modification of the Radical Law (Töpfer and Pillewizer 1966). The original Law computes the number of items to retain in a smaller scale dataset on the basis of the desired area taken up by those items on the smaller scale map. Following the format of their basic equation, the modification used here computes a relationship based on stream channel length:

$$length_{target} = length_{source} * \sqrt{\frac{RF_{source}}{RF_{target}}} \qquad (1)$$

Where:

$length_{target}$ is the summed length of channels after simplification to the target scale;

$length_{source}$ is the summed length of channels after pruning;

RF_{source} is the denominator of the Representative Fraction of the source scale; and

RF_{target} is the denominator of the Representative Fraction of the target scale.

Pruning is completed by iteratively eliminating reaches with UDA values that are less than a minimum tolerance. The tolerance value is increased for each iteration until the sum of retained stream lengths achieves the target value. Reducing total summed stream length reduces channel density for the subbasin. Pruning is localized to reaches that are furthest upstream to protect flow continuity and network topology. The modified Radical Law calculation is approximate, given the topological constraint and also given the constraint that stream reaches have varying lengths (only entire reaches are pruned). For the Missouri subbasin, the computation advises pruning the original 3,428 km of channels back to a summed length of 2,375 km for a scale jump from 24K to 50K (a reduction in stream length of 31 percent).

Complicating the pruning operation is the fact that pruning tends to homogenize channel density throughout the subbasin. Where substantial local differences in channel density exist (as for example in the West Virginia, Missouri, and Colorado subbasins), those differences are preserved by partitioning density levels and separately pruning each partition (Figure 2). In the Missouri subbasin, pruning reduced summed channel length by 1,070 km, from 1,921 km to 1,303 km in the lower density partition, and from 1,508 km to 1,056 km in the higher density partition. The total channel length after pruning was 2,359 km, a 31 percent reduction.

Additional Generalization

Following pruning, additional generalization either modifies or removes details from individual features. This is the stage at which physiographic differences impose the greatest impact on processing sequences. If they exist, swamp/marsh areas are aggregated; flood zone boundaries are smoothed; ponds and lakes are selected on a minimum size threshold (0.0008 km^2 for the 50K LoD); centerlines are substituted

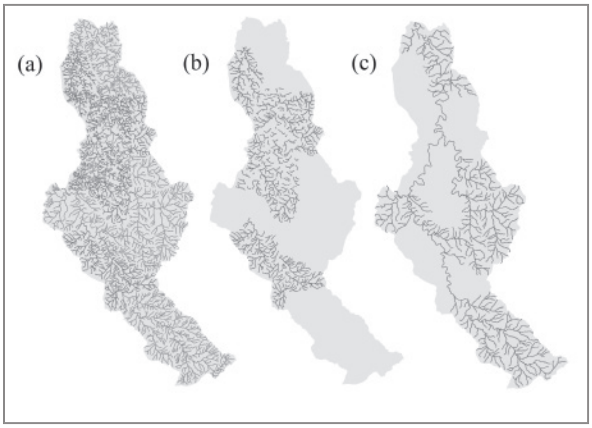


Figure 2. Density partitioning and pruning for the Missouri subbasin (C in Table 1): (a) original flowlines; (b) higher density channels after pruning; (c) lower density channels after pruning.

for polygonal river channels; and selected coordinates along flowlines are eliminated. Gaffuri (2007) argues for preservation of network outflow, which is performed in our approach using UDA. Six separate processing sequences have been fast-prototyped for the six subbasins in the different terrain-precipitation landscape regimes as discussed above (Table 1). Three of these prototype sequences are described below to demonstrate the variety of data modeling challenges unique to each landscape type.

The Upper Suwannee subbasin (**B** in Figure 1) spans the Florida-Georgia border and includes a portion of the Okefenokee Swamp. The landscape is flat and humid, with many small areas of standing water, marshland and swamps. The shape and size of individual polygons changes over time, thus the position or status of smaller individual polygons is not sacrosanct in generalizing to smaller mapping scales. Instead, the generalization challenge is to preserve the overall texture of swamps, marshes and small ponds in representations at smaller scales. Processing focuses on the swamp/marsh feature type, and involves an initial selection on size (> 0.02 km^2) to eliminate smallest polygons, rasterization (using 125 meter cells), pixel expansion to aggregate proximal polygons, re-vectorization, and then smoothing and merging to incorporate the modified feature type back into the NHD waterbody feature class. Figure 3 shows results of the 50K LoD processing in comparison to the source data (24K HR NHD) and an independently compiled benchmark data set at the nearest scale, the 100K MR NHD.

In comparing the three data versions visually in Figure 3, it is apparent that the generalized LoD retains much of the swamp/marsh texture, and displays better stream connectivity, relative to the source data. The LoD indicates a much higher area of swamps and marshes, relative to the 100K benchmark. It can be argued that the MR benchmark version implies a landscape which is comprised largely of dry land, which is not consistent with the HR source version.

In contrast to the landscape of swamps and marshes, subbasin **D**, along the Red River in Texas presents a landscape that is much drier with hilly terrain (Figure 4). The subbasin holds many hydrographic polygons but much of the hydrography is intermittent or ephemeral. Few waterbodies and areal features are permanent, and most are too small to be retained by the minimum size criteria, which creates problems for automatic delineation of a complete and continuous centerline for this NHD subbasin. Cartographic centerlines are delineated by spatial intersection with a set of artificial paths, which form a sequence of channel lines that flow through permanent water polygons (lakes, reservoirs, swamps, etc.) (Anderson-Tarver et

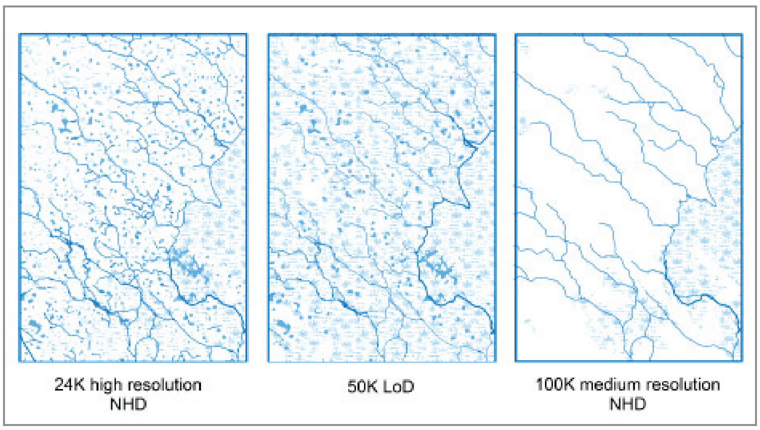


Figure 3. Results of processing the Florida-Georgia subbasin (B): (a) 24K high resolution NHD, (b) 50K LoD, and (c) 100K medium resolution NHD. The texture of swamps and marshes relative to the 24K source is acceptable in the LoD, although density of swamps and marshes appears to be under-generalized in the northwest corner. Most swamps and marshes are not contained in the 100K benchmark, implying a drier landscape than the 24K source.

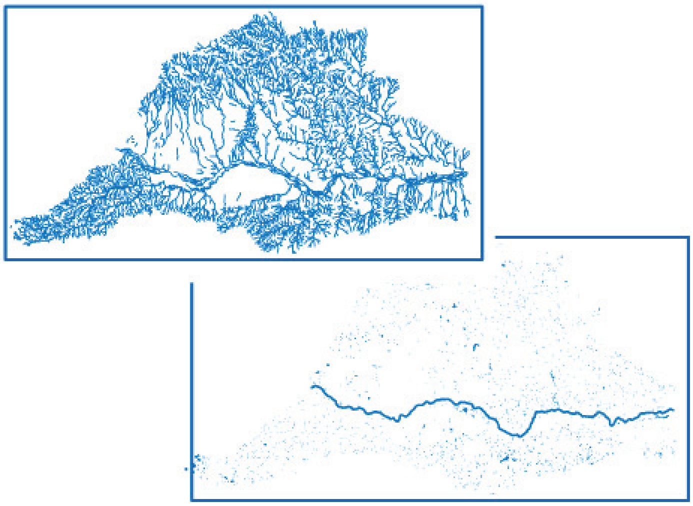


Figure 4. Texas subbasin (D), showing (a) NHD flowline network and (b) NHD water areas and water bodies, along with the primary flowline, parsed from the subbasin GNIS name. The majority of water polygons are ephemeral or too small to be included in a reduced scale LoD.

al. 2011). In many dry landscapes, such as this subbasin in Texas too few bodies of standing water exist to establish a centerline. In these cases, and responding to the cartographic convention of establishing a primary channel, the generalization processing delineates what we call a "primary flowline." The current delineation is parsed from the subbasin GNIS name. Current work to develop an automated solution is underway, based on UDA derived during database enrichment.

A second generalization challenge which arises in Texas subbasin **D** relates to the automatic delineation of a primary channel through a stream braid. Braiding occurs in humid and dry landscapes, thus an automated solution to delineating a continuous channel will benefit subbasins across the country. Figure 5 shows that the current automated processing does not completely resolve a single channel through the braid. Areal elimination, channel pruning and simplification results are more successful than is delineation of the primary channel, producing a 50K LoD containing a progressive reduction of detail between the 24K source and 100K benchmark which is appropriate to intermediate scale display.

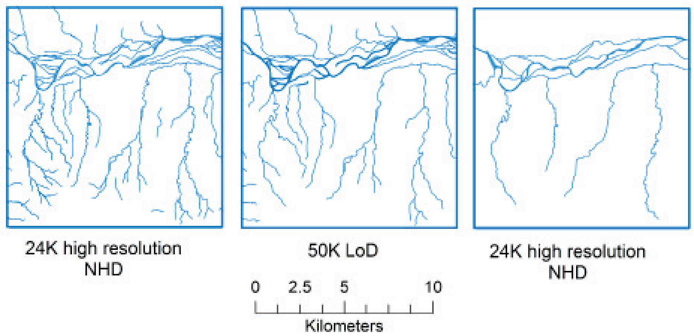


Figure 5. Results of processing the Texas subbasin (D): (a) 24K high resolution NHD, (b) 50K LoD, and (c) 100K medium resolution NHD. Generalization of linear and polygon features is acceptable. Delineation of a single primary channel continues to challenge a fully automated processing solution.

Subbasin **C** in Missouri demonstrates two generalization challenges, the first of which is stratifying stream channels to prune differing channel densities to differing tolerances; this was discussed in the pruning section. The second relates to the braided stream problem in Texas. In many NHD subbasins, even those in humid landscape types, the channels designated as artificial paths give neither a major channel nor a continuous path. A proposed solution (Figure 6) provides a continuous centerline by traversing the flowline graph and searching the UDA estimates derived from enrichment. The algorithm development is nearly

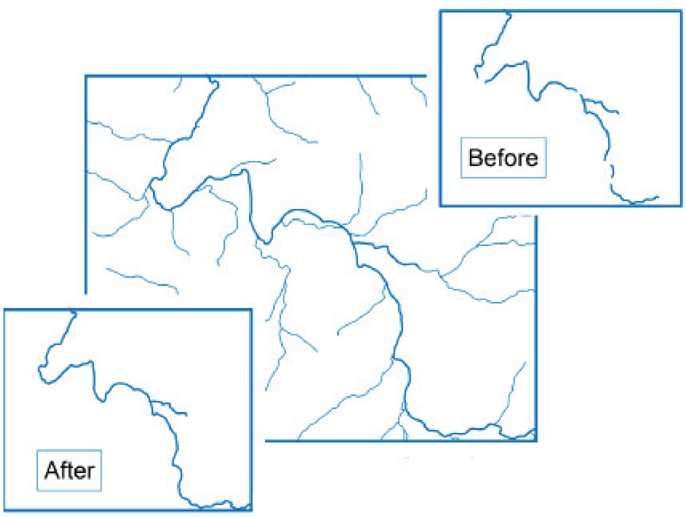


Figure 6. Automatic delineation of a single continuous centerline by searching node tables and upstream drainage area estimates.

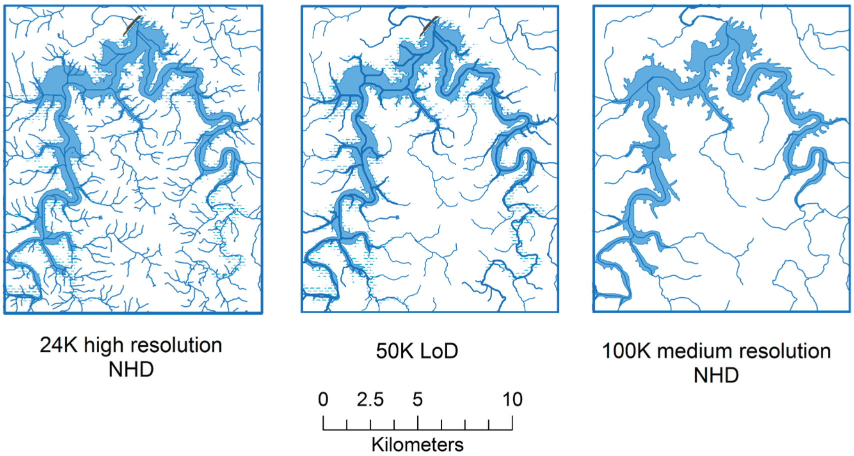


Figure 7. Results of processing the Missouri subbasin (C):): (a) 24K high resolution NHD, (b) 50K LoD, and (c) 100K medium resolution NHD. Centerlines are overlaid within the reservoir to show the outcomes of the continuous centerline processing. Notice that in the 100K benchmark (c), the dam (solid black polygon upper center) is not in the database. Likewise the inundation area surrounding the reservoir in the 24K source data (a) is eliminated from the 100K NHD data.

complete and will be applied to the braided stream problem in coming research.

Results of the generalization processing for Missouri are shown in Figure 7. Like many other humid landscapes, this subbasin contains very large reservoirs and inundation areas, and the figure illustrates how generalization processing affects these types of hydrographic features.

To summarize, generalization processing should and can be modified to reflect landscape variations which can impact the content and geometry of general hydrographic patterns. Collective pruning and additional generalization processing are referred to as "differential generalization." Pruning becomes differential when local density differences are stratified, as for example in regions which are partially glaciated, which cross several types of bedrock, or when moving from rural to urban areas. Additional generalization sequences model feature types (streams, canals, ponds, reservoirs, dams, etc.) differently to preserve local characteristics which are important for cartography or hydrologic analysis. In all types of differential generalization, the sequence of operations and/or the parameters are specific to regional terrain and climatic characteristics. Burghardt and Neun (2006) propose a constraint-based approach in which decisions are made automatically about which type of pruning or other generalization methods to apply, which is not currently accomplished in the described approach.

Metric Assessment

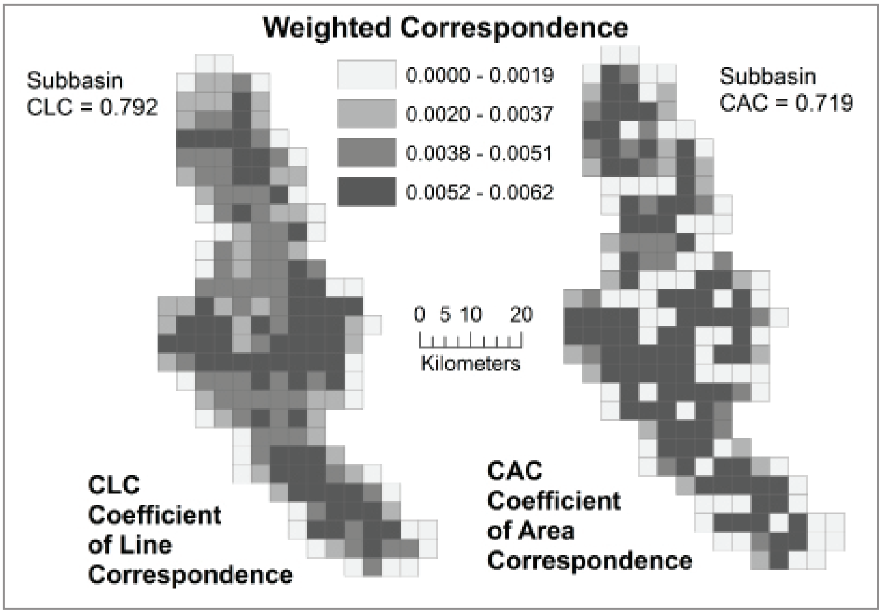
The benchmark for assessment is the MR (100K) NHD. Metric assessment includes two measures of feature conflation, identifying features which correspond in the 50K LoD and in the 100K benchmark. (Recall that the 50K LoD is intended for use in the scale range of 50K to 200K). The Coefficient of Line Correspondence (CLC) (Stanislawski et al. 2010) computes conflation among stream channels on the basis of length. Length preservation forms one of the most important measures of the amount of preserved detail in a generalized line (Cromley and Campbell 1990).

$$CLC = \frac{\sum \text{conflation}}{\sum \text{conflation} + \sum(\text{omissions} + \text{commissions})} \qquad (2)$$

where:
conflation refers to the length of channels common to LoD and benchmark;
omissions refers to the length of channels in 100K benchmark but not in LoD; and
commissions refers to the length of channels in LoD but not in 100K benchmark.

CLC values range from 1.0 (perfect correspondence) to 0.0 (total mismatch). Features are buffered to correctly pair generalized features with benchmark features. The buffer size for hydrographic features combines horizontal positional accuracy estimates for the two versions of NHD (LoD scale and benchmark scale), spanning twice the tolerance for well-defined points from the UNITED STATES. National Map Accuracy Standards (NMAS) at the two scales. The NMAS tolerance at 50K and 100K is 0.02 inch, or 0.5 mm (UNITED STATES. Bureau of the Budget 1947) at each

Figure 8. Gridded CLC (a) and CAC (b) metrics for subbasin C comparing the 50K LoD with the 100K NHD benchmark. Better length correspondence is evident in the less dense portions of the stream network, where pruning has a weaker impact on overall channel structure. CAC values are lower in part because of the absence of some feature types in the 100K benchmark, as noted in the text.



scale, which provides a buffer distance of 152.4 ground meters. The coefficient of area correspondence (CAC) is analogous to the CLC and compares polygonal features by computing matches and errors of omission and commission in area. While the CLC measures conflation of full stream reaches, the CAC includes full and partial conflations for polygonal features.

To get a clear sense of how conflation varies across a subbasin, we overlay a grid of 200 cells and compute CLC and CAC values for each grid cell (weighted by the amount of subbasin coverage in each cell, to avoid edge bias). CAC values also range from 1.0 (perfect match) to 0.0 (no match). Figure 8 illustrates the CLC and CAC values for the Missouri subbasin.

Validation

The previous discussion presented processing sequences for several subbasins; in the space available to this paper, validation procedures are demonstrated for only one of these, the humid hilly subbasin in Missouri. Emphasis of this paper is on presenting a methodology for generalization, assessment, and validation, rather than on reaching conclusions per se about comparisons or distinctions between hydrography in one subbasin or another.

The processing sequence applied to Missouri subbasin C was also applied, without changing the sequence or parameters, to NHD features for a nearby subbasin (G) along the Cimarron River in Oklahoma (Figure 9). The subbasin

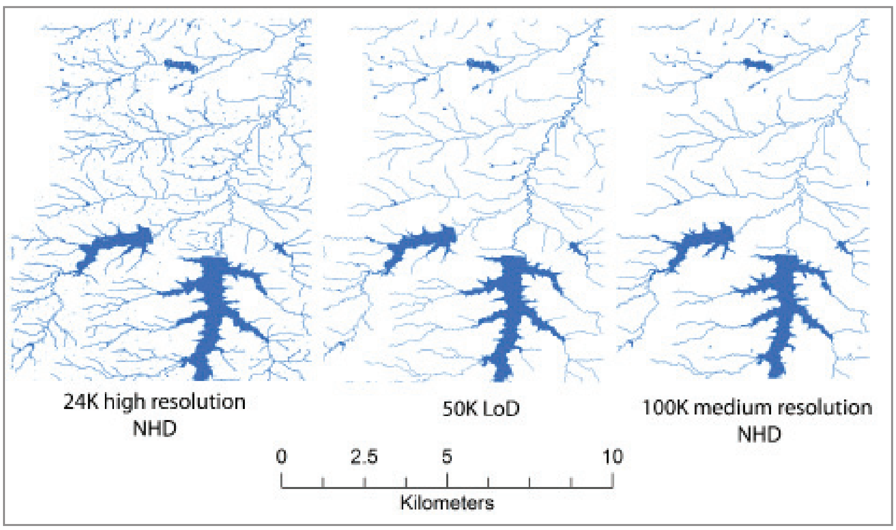


Figure 9. Results of processing the Oklahoma subbasin (G). Panels have been rotated to format onto the page; north is to the left. The 100K benchmark dataset contains nearly as much standing water as the processed 50K LoD; pruning and flowline simplification parameters set for the Missouri subbasin appear to apply well to this subbasin as well, at this mapping scale.

lies within 300 km of the Missouri subbasin and covers 3,570 sq km. Terrain for the Oklahoma subbasin is less hilly than Missouri and at a lower elevation. Runoff estimates for the Oklahoma subbasin are about half the Missouri subbasin, and channel density is uniformly high. Channels were therefore not stratified prior to pruning.

The purpose of validation is to determine a geographic range for which one of the generalization processing sequences can be applied with appropriate intermediate scale results. To determine this, we compute CLC and CAC metrics, using the Oklahoma 100K NHD as a benchmark (Figure 10). Comparison of CLC and CAC values (Table 2) indicates that applying the processing sequence designed for the Missouri subbasin to the Oklahoma subbasin results in a very good quality for line correspondence, but a lesser quality area correspondence. A bootstrap analysis can generate confidence intervals to infer if differences between the two pairs of metrics are significant, and is described in Stanislawski et al. (2010a).

The CLC and CAC measures provide a method of evaluating the consistency of pruning and generalization across subbasins in comparison to an existing benchmark. Comparison of values in Table 2 indicates 74-percent average correspondence between the 50K LoDs and 100K NHD benchmarks, which we consider to be a relatively high level of consistency. The CLC and CAC take a first step towards metric assessment of generalization outcomes, and we look forward to other researchers suggesting additional metrics.

Table 2. Subbasin metrics compared for two physiographically similar subbasins, processed with a single processing sequence.

Subbasin	*CLC*	*CAC*
C Pomme De Terre River, Missouri	0.792	0.719
G Lower Cimarron River, Oklahoma	0.830	0.623

Summary

Landscape differences made manifest by local physiography and local climate require differing generalization sequences for effective multiscale representation of hydrography. Algorithms and parameters as well as processing sequences must vary to retain these differences for cartographic purposes, such as base topographic mapping, and for purposes of regional hydrologic analysis, such as modeling flow and accumulation. This paper reports on recently completed work on a selection of NHD subbasins sampled from automatically derived landscape types. Generalization procedures for the NHD rely on database enrichment of ancillary variables (UDA values, local channel densities, and attribution of continuous centerlines) that sup-

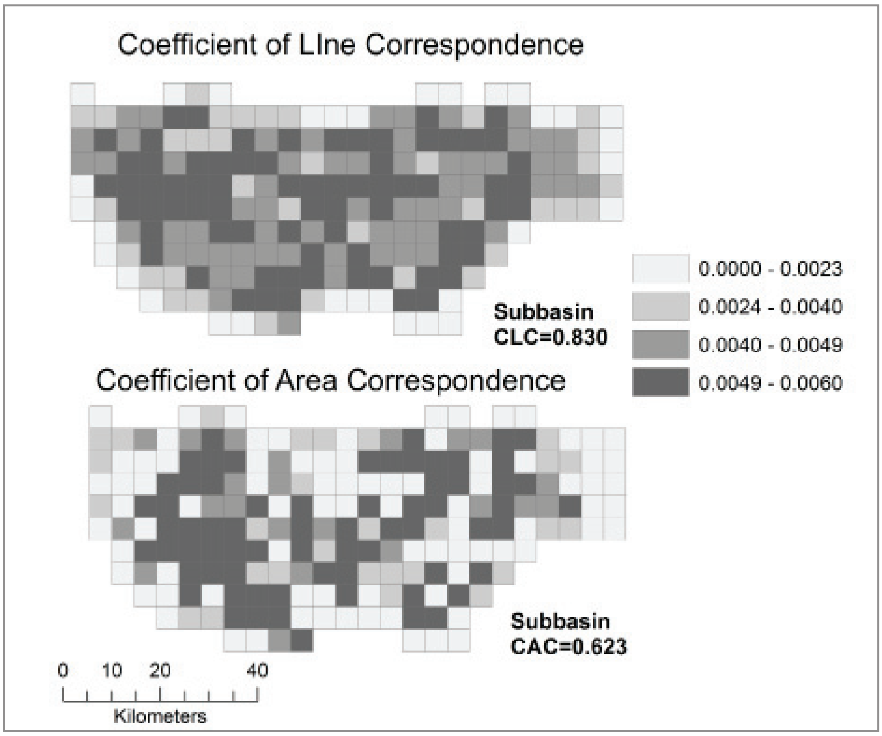


Figure 10. Gridded CLC (a) and CAC (b) metrics for subbasin G comparing the 50K LoD with the 100K NHD benchmark. Lower length correspondence is found near the subbasin pour point where artificial paths do not match within large waterbodies.

port differential pruning and generalization. The CLC and CAC furnish simple, consistent methods to compare generalization results to benchmark data in a spatially distributed manner. As such, these metrics are effective tools for finding isolated problems and refining generalization procedures as needed.

Methods described in this paper are designed for processing hydrographic data. To date, we have worked with roughly two dozen hydrographic subbasins situated in rural areas. We are currently testing the approach on two metropolitan areas to identify possible issues caused by urban features, such as differentiating ditches and canals from natural stream channels, working with stream channel discontinuities, etc. Further research will apply regional hydrographic landscape types to subbasins, in order to derive, through modelling, blended processing sequences and parameters that maintain natural transitions between landscape boundaries. In addition, validation of generalization outcomes could be compared with DEM-derived streams for completeness, and to insure that total displacement does not compromise overall generalization objectives. One goal of the work reported here is to distribute the generalization and processing sequences in the form of an ESRI Arc Toolbox, and software development will continue towards that goal in coming research.

ACKNOWLEDGEMENTS

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REFERENCES

Anderson-Tarver, C., B.P. Buttenfield, L.V. Stanislawski and J.M. Koontz. 2011. Automated delineation of stream centerlines for the USGS National Hydrography Dataset. In: *Proceedings of the 25th International Cartographic Conference (ICC2011)*, Paris, France.

Bobzien, M., D. Burghardt, I. Petzold, M. Neun and R. Weibel. 2008. Multi-representation databases with explicitly modeled horizontal, vertical, and update relations. *Cartography and Geographic Information Science* 35(1): 3-16.

Brewer, C. A., B.P. Buttenfield, and E.L. Usery. 2009. Evaluating generalizations of hydrography in differing terrains for *The National Map* of the United States. In: *Proceedings of the 24th International Cartographic Conference (ICC2009)*, Santiago, Chile.

Burghardt, D. and M. Neun. 2006. Automated sequencing of generalization services based on collaborative filtering. In: *Proceedings of the 4th International Conference on Geographic Information Science (GIScience'2006)*, Muenster, Germany, 28: 41-46.

Buttenfield, B.P., L.V. Stanislawski and C.A. Brewer. 2010. Multiscale representations of water: Tailoring generalization sequences to specific physiographic regimes. Short Abstract. In: *Proceedings of the 6th International Conference on Geographic Information Science (GIScience'2010)*, Zurich, Switzerland.

Buttenfield, B.P. and C. Frye. 2006. The fallacy of the "golden feature" in MRDBs: Data modeling versus integrating new anchor data. In: *Proceedings of the 11th ICA Workshop on Generalisation and Multiple Representation*, Portland, Washington. Online: *http://aci.ign.fr/Portland/paper/ICA2006-Buttenfield.pdf*. (accessed 8 March 2011).

Carlston, C.W. 1963. *Drainage density and streamflow. Physiographic and Hydraulic Studies of Rivers*. United States Geological Survey Professional Paper 422-C.

Cecconi, A., R. Weibel and M. Barrault. 2002. Improving automated generalization for on-demand web mapping by multiscale databases. In: *Proceedings of the International Symposium on Geospatial Theory, Processing, and Applications*, Ottawa, Canada.

Chaudhry, O. and W.A. Mackaness. 2008a. Automatic identification of urban settlement boundaries for multiple representations databases. *Computers, Environment and Urban Systems* 32: 95-109.

Chaudhry, O., and W.A. Mackaness. 2008b. *Partitioning techniques to make manageable the generalization of national spatial datasets*. 11th ICA Workshop on Generalisation and Multiple Representation, Montpellier, France. Online: *http://aci.ign.fr/montpellier2008/papers/21_Chaudhry_Mackaness.pdf* (accessed 8 March

2011).

Chaudhry, O. and W.A. Mackaness. 2008c. Creating mountains out of mole hills: Automatic identification of hills and ranges using morphometric analysis. *Transactions in GIS* 12(5): 567-589.

Cromley, R.G., and G.M. Campbell. 1990. A geometrically efficient bandwidth line simplification algorithm. In: *Proceedings of the 4th International Symposium on Spatial Data Handling*, Zurich, Switzerland, 1: 77-84.

Deng, Y. 2007. New trends in digital terrain analysis: Landform definition, representation, and classification. *Progress in Physical Geography* 31(4): 405-419.

Dent, B.D. 1999. *Cartography, Thematic Map Design. 5th edition*. Boston: WCB/McGraw Hill.

Fathi, A. and J. Krumm. 2010. Detecting road intersections from GPS traces. In: *Proceedings of GIScience'2010*, Zurich, Switzerland. LNCS 6292: 56-69.

Fenneman, N.M. and D.W. Johnson. 1946. *Physical Divisions of the United States*. Washington DC: USGS. Special map series, scale 1:7,000,000 (polygon coverage derived from map at *http://water.usgs.gov/GIS/metadata/usgswrd/XML/physio.xml*, accessed 8 March 2011).

Fisher, P., J. Wood and T. Cheng. 2004. Where is Helvellyn? Fuzziness of multi-scale landscape morphometry. *Transactions of the Institute of British Geographers* 29(1): 106-128.

Gaffuri, J. 2007. Outflow preservation of the hydrographic network on the relief in map generalization. In: *Proceedings of the 23rd International Cartographic Conference (ICC2005)*, Moscow, Russia.

Grohmann, C.H., M.J. Smith and C. Riccomini. 2009. Surface roughness of topography: A multi-scale analysis of landform elements in Midland Valley, Scotland. In: *Proceedings of Geomorphometry 2009*, Zurich, Switzerland.

Montgomery, D.R. and W.E. Dietrich. 1989. Source areas, drainage density, and channel initiation. *Water Resources Research* 25(8): 1907-1918.

Reed, J.C. and C.A. Bush. 2005. *Generalized geologic map of the United States, Puerto Rico, and the UNITED STATES*. Virgin Islands. United States Geological Survey. *http://pubs.usgs.gov/atlas/geologic/* (accessed 8 March 2011).

Robinson, A.H., J.L. Morrison, P.C. Muehrcke, A.J. Kimerling and S.C. Guptill. 1995. *Elements of Cartography, 6th edition*. New York: John Wiley & Sons.

Schmidt, J. and R. Andrew. 2005. Multi-scale landform characterization. *Area* 37(3): 341-350.

Slocum, T.A., R.B. McMaster, F.C. Kessler and H.H. Howard. 2009. *Thematic Cartography and Geovisualization, 3rd edition*. Upper Saddle River, New Jersey: Pearson/Prentice Hall.

Stanislawski, L.V. 2009. Feature pruning by upstream drainage area to support automated generalization of the United States National Hydrography Dataset. *Computers, Environment and Urban Systems* 33(5): 325-333.

Stanislawski, L.V., B.P. Buttenfield, and V.A. Smaranayake. 2010, *Generalization of hydrographic features and automated metric assessment through bootstrapping*. 12th ICA Workshop on Generalisation and Multiple Representation, Zurich, Switzerland. Online: *http://aci.ign.fr/2010_Zurich/genemr2010_submission_11.pdf* (accessed 8 March 2011).

Stanislawski, L.V., B.P. Buttenfield and M. Finn. 2011. Integrating hydrographic generalization over multiple physiographic regimes. In: *Proceedings of the Generalization and Data Integration Symposium (GDI 2010)*, Boulder, Colorado.

Stanislawski, L.V., B.P. Buttenfield, M. Finn and K. Roth 2009. Stratified Database Pruning to Support Local Density Variations in Automated Generalization of the United States National Hydrography Dataset. In: *Proceedings of the International Cartographic Association Conference*, Santiago, Chile.

Stanislawski, L.V, M. Finn, E.L. Usery and M. Barnes. 2007. Assessment of a rapid approach for estimating catchment areas for surface drainage lines. In: *Proceedings of ACSM-IPLSA-MSPS*, St. Louis, Missouri.

Tarboton, D.G., R.L. Bras and I. Rodriguez-Iturbe. 1992. A physical basis for drainage density. *Geomorphology* 5(1992): 59-76.

Töpfer, F., and W. Pillewizer. 1966. The principles of selection. *The Cartographic Journal* 3: 10-16.

Touya, G. 2008. First thoughts for the orchestration of generalisation methods on heterogeneous landscapes. In: *Proceedings of the 11th ICA Workshop on Generalisation and Multiple Rep-

resentation. Montpellier, France. Online: *http://aci.ign.fr/montpellier2008/papers/01_Touya.pdf* (accessed 8 March 2011).

Touya, G., C. Duchêne and A. Ruas. 2010. Collaborative generalization: Formalisation of generalisation knowledge to orchestrate different cartographic generalization processes. In: *Proceedings of GIScience 2010*, Zurich, Switzerland. Berlin: Springer LNCS 6292: 264-278.

Tucker, G.E. and R.L. Bras. 1998. Hillslope processes, drainage density, and landscape morphology. *Water Resources Research* 34(10): 2751-2764.

UNITED STATES. Bureau of the Budget. 1947. *United States National Map Accuracy Standards*. Washington DC: UNITED STATES. Bureau of the Budget.

USGS. 2000. *The National Hydrography Dataset: Concepts and Contents*. United States Geological Survey. Online: *http://nhd.usgs.gov/chapter1/-index.html* (accessed 15 February 2011).

van Oosterom, P. and V. Schenkelaars. 1995. The development of an interactive multi-scale GIS. *International Journal of Geographical Information Systems* 9(5): 489-507.

Wolock, D.M and G.J. McCabe. 1999. Estimates of runoff using water-balance and atmospheric general circulation models. *Journal of the American Water Resources Association* 35(6):1341-1350.

Wood, J. 1996. *The Geomorphological Characterisation of Digital Elevation Models*. PhD thesis, University of Leicester, UK. Online: *http://www.soi.city.ac.uk/~jwo/phd//* (accessed 8 March 2011).

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The U.S. Geological Survey Cartographic and Geographic Information Science Research Activities 2006 – 2010

E. Lynn Usery

Contributions to this report were made by Cynthia Brewer, Barbara Buttenfield, Keith Clarke, Michael P. Finn, Steve Helterbrand, Barbara Poore, Thomas Shoberg, Larry Stanislawski, and Dalia Varanka.

The U.S. Geological Survey (USGS) produces geospatial databases and topographic maps for the United States of America. A part of that mission includes conducting research in geographic information science (GIScience) and cartography to support mapping and improve the design, quality, delivery, and use of geospatial data and topographic maps. The Center of Excellence for Geospatial Information Science (CEGIS) was established by the USGS in January 2006 as a part of the National Geospatial Program Office. CEGIS (*http://cegis.usgs.gov*) evolved from a team of cartographic researchers at the Mid-Continent Mapping Center. The team became known as the Cartographic Research group and was supported by the Cooperative Topographic Mapping, Geographic Analysis and Monitoring, and Land Remote Sensing programs of the Geography Discipline of the USGS from 1999-2005. In 2006, the Cartographic Research group and its projects (*http://carto-research.er.usgs.gov/*) became the core of CEGIS staff and research. In 2006, CEGIS research became focused on *The National Map* (*http://nationalmap.gov*).

With the establishment of CEGIS, the USGS took advantage of an existing contract with the National Research Council (NRC) of the American National Academy of Sciences to develop *A Research Agenda for Geographic Information Science at the U.S. Geological Survey* (*http://books.nap.edu/catalog.php?record_id=12004*) (NRC, 2007). The NRC completed and published the report in December 2007. The research agenda in the NRC report then became the basis for CEGIS research to support *The National Map* and advance the National Spatial Data Infrastructure (NSDI) of the United States. Initiation in 2008 of the research recommendations of the NRC was facilitated by the fact that several ongoing CEGIS research projects were identified as short-term (2 to 4 years) high priority by the NRC. These include developing an ontology for *The National Map*, automated data integration and generalization. The NRC also recommended additional high priority short-term projects including User-Centered Design for Web Map Services and Design of an Electronic Topographic Map. Long term (4 to 8 years) projects recommended by the NRC centered on developing ontology-driven, spatio-temporal, quality-aware, and transaction processing data models.

CEGIS Research Activities

Based on the NRC recommendations and other research needs for *The National Map* identified within the USGS, CEGIS established six short term inter-related research projects. These projects address immediate objectives of *The National Map* to investigate new methods for information access and dissemination, automated data integration and generalization, and knowledge organization systems, which are

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formalized specifications of domain knowledge that include taxonomies, thesauri, gazetteers, and ontologies. They provide important authoritative or community-sanctioned domain knowledge in forms that are explicit and shareable by both humans and computational systems. The projects included:

- Geographic Feature Ontology for *The National Map*.
- Automated Data Integration.
- Generalization.
- User-Centered Design for Web Services.
- Electronic Topographic Map Design.
- Multi-Resolution Raster Data, including rapid projection and an application to sea level rise.

The results of these projects to date (September 2010) are briefly documented in the remainder of this article.

Geographic Feature Ontology for The National Map

Ontologies specify feature semantics for richer data models. New data models and associated knowledge organization systems for *The National Map* can translate traditional topographic information into a flexible spatiotemporal knowledge base that can serve many different application areas. In 2009, CEGIS sponsored a Specialist Meeting on "Developing and Ontology for *The National Map*." Participants in the Specialist Meeting developed short position papers and provided insight on the construction of the ontology. Six of the papers were published in *Cartographica* (Varanka and Usery 2010). A feature ontology has been developed for the topographic features present in *The National Map* databases. The ontology was constructed using previous USGS classifications of topographic features including Digital Line Graph-Enhanced (DLG-E), Digital Line Graph-Feature (DLG-F), and the National Hydrography Dataset (NHD) formal specifications and the current Best Practices Data models to provide a basis for a new ontology that can support *The National Map* (Varanka 2009). The developed ontology includes:

- Terrain – includes 58 USGS landform features, such as arch, delta, moraine, sink.
- Surface Water – features and relations derived primarily from DLG terms now incorporated in the NHD.
- Ecological Regimes – classifications are based primarily on their user applications
- Built-up Areas – classified using the US. Census Bureau North America Industry Classification System (US. Census 2007): includes 180 features categorized in subclasses including transportation and warehousing; entertainment and recreation; utilities; resource extraction; structures; agriculture and fishing; and others.
- Divisions – includes 45 features from survey lines, civil government units, and boundaries.
- Events – includes eight security features, such as hazard, earthquake, floods and six historical site features, such as archaeological site and historical marker.

Recent research activity for this project has focused on the Semantic Web and the USGS has made available nine research datasets from the National Map databases in the Resource Description Framework (RDF) triple format. These datasets are accessible from a public server provided by CEGIS with a SPARQL endpoint (*http://131.151.2.169:8890/sparql*) to support semantic query capability (Varanka et al. 2010).

Automated Data Integration

Integrating spatial data sets from a wide range of sources presents a fundamental research challenge for *The National Map* and CEGIS research. Spatial data sets at disparate scales, resolutions, and quality are difficult to fuse or merge, and there is a series of issues in bringing these disparate data together for spatial analysis and decision making. The most basic challenge involves the compatibility of the geometry. Accomplishments include developing an empirical standard for geometric error that still supports integration in the visual presentation and the embryonics of a theory of integration based on scale and resolution (Usery et al. 2009a). Additionally, developments of collaborators include an automated method of integrating vector transportation with orthographic images (Knoblock and Shahabi 2007).

The conflation of surface water features and Digital Elevation Models (DEMs) is also being investigated using light detection and ranging (lidar) data. Initial work has examined commercial software offerings for drainage network extraction and comparing results from different algorithms against each other and against existing hydrographic networks such as NHD (Clarke and Archer 2009).

Geophysical Data Conflation and Integration

Geophysical data, which are derived from the underlying geology of an area and fundamentally interpreted through precise geospatial coordination, present a research challenge for data integration. It is the integration of geophysical data within a precise geospatial framework that provides the first and most basic challenge. CEGIS research currently involves the study of precisely locating point geophysical data from pre-GPS era surveys using *The National Map* as a reference system (Shoberg et al. in review) as well as conflating high precision local survey geophysical data with stations of unknown quality from national databases (Shoberg and Stoddard, in review). Further CEGIS is researching how reliable standard algorithms used to generate raster surfaces and grid data can be interpolated for very low density, highly asymmetric point source theoretical data (Shoberg 2010).

Generalization

Providing an operational capability for automated multi-scale display and delivery of The National Map and other USGS geospatial data requires generalization procedures. Research has focused on developing automated cartographic generalization for the hydrography theme to furnish, from high-resolution data, smaller scale representations, or intermediate levels of detail that are sufficient for a range of topographic map scales. Automated procedures include phases for data enrichment, feature pruning, tailored generalization operations, and validation. Data enrichment involves processing that adds prominence and density estimates to features for subsequent generalization and symbolization operations. Prototype sequences for feature simplification and other generalization operations have been tailored for primary terrain and climate conditions, which, through an automatically derived national classification system, will be smoothly blended over the span of natural physiographic conditions in the country. Validation uses conflation to separately compare generalized line and area features with suitable benchmark data to produce spatially distributed line and area correspondence metrics. A second form of validation establishes a geographic range over which tailored generalization sequences produce satisfactory results, in an effort to implement a parsimonious set of data processing sequences for the nation. Aside from developing a framework to smoothly transition generalization sequences over the range of conditions, future work will focus on testing and implementing similar strategies for generalization of other data themes.

CEGIS Research Symposium: GDI 2010: Generalization and Data Integration

As a part of Generalization Initiative activities, USGS funded a research symposium in Boulder, CO June 20-22, 2010. The Environmental Systems Research Institute (ESRI) provided some additional funding. The symposium focused on current accomplishments and current challenges for generalization of spatial data, with special emphasis on data modeling and data integration. Significant progress has been made in recent years on generalization for scale-change and topographic base mapping, and on design and construction of Multi-Resolution Databases (MRDBs). European national mapping agencies have been especially active in automatic data modeling and agent-based generalization. Current impediments to building fully functional MRDBs relate to integrating various data representations. Data integration continues to challenge links between multiple representations, data fusion, conflation, conflict resolution, and other data modeling tasks. The goal of the symposium was to catalyze discussion and collaboration between the data integration and generalization communities; to identify problems which can be addressed given current state of knowledge, and to prioritize challenges which remain. Throughout discussion, emphasis was centered on national mapping.

Thirty-two researchers from eight countries and nine students from four universities participated in the symposium, held on the University of Colorado campus. Intermixed plenary and small group sessions on three aspects of generalization, national mapping and data integration accomplished several important objectives. Members of national mapping agencies from several countries shared information about progress and special challenges to data processing and integration in national mapping efforts. Academic perspectives informed the discussion on current and emerging methods for processing and for assessing uncertainty. Impacts of volunteered geographic information (VGI) and user-generated content (UGC) entered discussions throughout the symposium.

A research volume based on the symposium is underway, to be co-edited by the three faculty affiliates to CEGIS (Professors Buttenfield, Brewer and Clarke). The volume will include a summary of the symposium as well as papers submitted by participants detailing empirical results and research problems relevant to generalization and data integration. A report to USGS is nearly complete, and a 50-minute briefing on the symposium was presented at the ICC Commission Workshop on Generalization and Multiple Representations, held in Zurich Switzerland at the GIScience 2010 conference in September (*http://ica.ign.fr/2010_Zurich/slides/2010-ICAWSGene-Invited-Buttenfield.pdf*).

User-Centered Design for Web Services

Improving usability of the human interface, providing easy access to high-quality maps in various media, and high-quality printing for all users is the focus of the User-Centered Design project. CEGIS is conducting research that will transform the well-designed traditional paper topographic maps into an easy-to-use electronic, web-based, multipurpose utility for a variety of users. Research over the past two years has focused on defining the user base for *The National Map* through nationwide interviews and surveys. These surveys revealed the importance of new trends in user creation of data with online mapping platforms and social media. The USGS held a workshop on VGI in 2010 and began a pilot project testing how user generated data can be incorporated into *The National Map* databases. A second workshop will be held in the spring of 2011 on data licensing issues on the geospatial web. CEGIS researchers have also been active in related fields of cyberinfrastructure and ontology research.

Electronic Topographic Map Design

Topographic maps are the one of the most important products of the USGS and *The National Map*. Two research foci of electronic topographic map design are of particular and immediate value to the cartographic display of *The National Map*: (1) development of PDF topographic maps for wide distribution and (2) development of foreground and background data layers for control of visual hierarchies in each of the eight data layers for which USGS has responsibility in *The National Map*.

Designs for multiscale map presentations have been developed in cooperation with The Pennsylvania State University. One emphasis of the project is incorporation of generalized hydrography produced at The University of Colorado at Boulder, and collaboration between CEGIS, PSU, and CU has been closely coordinated. The map designs balance display changes with geometry changes through scale. For example, line coalescence problems at smaller scales may be solved by eliminating feature types and using thinner line symbols (example display changes), by applying simplification, collapse, and amalgamation operations to features (example geometry changes), or using both approaches together. The maps are also fully labeled, and a challenge of the project has been to retain dynamic automated labeling by continuously refining geographic information system labeling rules so that later data updates may be moved readily onto the topographic maps. In addition to design adjustments that respond to scale change, the maps are evaluated using multiple resolutions — onscreen 91 ppi (desktop), 120 ppi (laptop), print 400 ppi — and to multiple formats (PDF, ArcMap, cached tiles for web display, paper) to accommodate varied map reading contexts. Preliminary work and updates on progress on this multiscale topographic mapping project is posted at *http://ScaleMaster.org* (see also Brewer et al. 2009, 2010; Brewer and Buttenfield 2007, 2010; Brewer and Akella 2008).

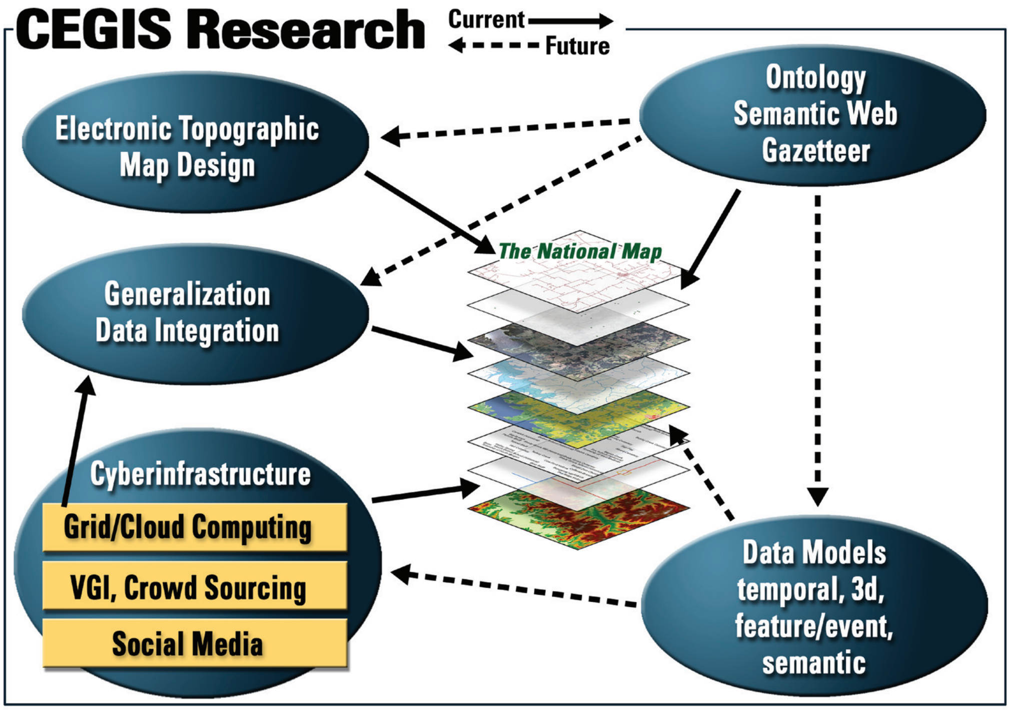

Figure 1. CEGIS current and future research projects.

Multi-Resolution Raster Data

This project is composed of two tasks, the first on rapid projection of raster databases and the second on an application in a global model and animation of sea level rise. The focus of the rapid projection task was to develop a Web implementation (to include analyses of high-performance computing technologies) for accurate reprojection and resampling of raster data for *The National Map*. Results include an implemented USGS software package, mapIMG on a variety of platforms, new categorical resampling methods that allow significantly better preservation of categories when downsampling, a resampler for data of counts, such as population numbers, and the development of an object-oriented public-domain version of the General Cartographic Transformation Package. The mapIMG software serves as the basis for future development for issues of map projection of large (multi gigabyte) databases over the Web. All software and test data are open source and are available at *http://cegis.usgs.gov/multiscale_databases.html*.

The focus of the application task was to develop projection methods for global model with an initial application to modeling and animating sea level rise. The developed model included 30-arcsec resolution global elevation, population, and land cover and for the coastal United States 30 m resolution data for the same datasets. Results include sea level rise animations for the world and the United States coasts (*http://cegis.usgs.gov/sea_level_rise.html*) (Usery et al. 2009b).

Current and Future Research

The CEGIS research agenda established from the recommendations from the NRC report has evolved to include work with the Semantic Web, online digital gazetteers that are ontology-driven, and efforts to tap the exploding phenomena of social media, crowd sourcing, and VGI. These activities are classed in a large project on cyberinfrastructure that is being researched in the context of *The National Map*. Additional CEGIS research currently beginning focuses on spatiotemporal, three-dimensional, feature/event-based, and semantic data models. Figure 1 shows the structure and inter-relations of CEGIS current and future research.

REFERENCES

Anderson-Tarver, C. 2010. *Generalizing a Swamp-Marsh Database Using Texture*. Unpublished Master's Thesis, Department of Geography, University of Colorado-Boulder.

Anderson-Tarver, C., S. Leyk and B.P. Buttenfield. 2010. Identifying feature textures using fuzzy sets. In: *AutoCarto Proceedings 2010*, Orlando, Florida.

Brewer, C.A., C.L. Hanchett, B.P. Buttenfield and E.L. Usery. 2010. Performance of Map Symbol and Label Design with Format and Display Resolution Options Through Scale for The National Map. In: *Proceedings of AutoCarto 2010*, Orlando, FL (CD-ROM).

Brewer, C.A. and M.K. Akella. 2008. Multi-resolution Multi-scale Topographic Map Design: Toward a New Look for The National Map. In: *Proceedings of AutoCarto 2008*, Shepherdstown WV (CD-ROM).

Brewer, C.A. and B.P. Buttenfield. 2007. Framing Guidelines for Multi-Scale Map Design Using Databases at Multiple Resolutions. *Cartography and Geographic Information Science* 34(1): 3-15.

Brewer, C.A. and B.P. Buttenfield. 2010. Mastering map scale: Balancing workloads using display and geometry change in multi-scale mapping. *Geoinformatica* 14(2): 221¬239 (published as Open Access in May 2009: DOI 10.1007/s10707-009-0083-6).

Brewer, C.A., B.P. Buttenfield and E.L. Usery. 2009. Evaluating Generalizations of Hydrography in Differing Terrains for The National Map of the United States. In: *Proceedings of the International Cartographic Conference*, Santiago, Chile.

Buttenfield, B.P., L.V. Stanislawki and C.A. Brewer. 2010. Multiscale Representations of Water: Tailoring Generalization Sequences to Specific Physiographic Regimes. In: *Proceedings of GIScience 2010*, Zurich, Switzerland. (refereed extended abstract on USB).

Buttenfield, B.P., L.V. Stanislawski and C.A. Brewer. 2011. Adapting generalization tools to physiographic diversity for the United States National Hydrography Dataset. *Cartography and Geographic Information Science* 38(3): 289-301.

Clarke, K.C. and R. Archer. 2009. Terrain Feature Extraction from Variable Resolution Digital Elevation Models. In: *Proceedings of the International Cartographic Conference*, Santiago, Chile.

Finn, M. P., J. R. Trent and R. A. Buehler. 2006. *User's Guide for the MapImage Reprojection Software Package, Version 2.1*. U. S. Geological Survey Open-File Report 2006-1016.

Guan, Q, M.P. Finn, E.L. Usery and D.M. Mattli. 2009. *Rapid Raster Projection Transformation and Web Service Using High-Performance Computing Technology*. Paper presented at the Association of American Geographers Annual Meeting, Las Vegas, NV.

Knoblock, C. and C. Shahabi. 2007. Geospatial Data Integration. In J. Wilson and A. Fotheringham (eds.), *Handbook of Geographic Information Science*. Oxford: Blackwell, pp. 185-196.

NRC. 2007. *A Research Agenda for Geographic Information Science at the United States Geological Survey*, National Research Council, The National Academies Press, Washington DC.

Poore, B. (forthcoming). Going cyber: Users as Essential Contributors to Spatial Cyberinfrastructures. In: *Proceedings of the National Academy of Science*.

Poore, B. and U.S. Geological Survey and Open Geospatial Consortium. 2010. In: B. Wharf (ed.), *Encyclopedia of Geography*. Thousand Oaks, CA: Sage Publications.

Poore, B. 2010. Wall-E and the 'Many, Many Maps': Toward User-centered Ontologies for The National Map. *Cartographica* 45(2): 113-120.

Shoberg, T., P.R. Stoddard and M.P. Finn. In review. *Rejuvenating pre-GPS era Geophysical Surveys Using The National Map*.

Shoberg, T. and P.R. Stoddard. In review. *Integrating Stations for the National Gravity Database into a Local GPS-based Land Gravity Survey*.

Shoberg, T., 2010. Integrating Geophysical, Geologic and Geospatial Data. In: *Proceedings of the Generalization and Data Integration (GDI 2010) Symposium*, Boulder, Colorado (Abstract).

Stanislawski, L.V. 2008. *Development of a knowledge-based network pruning strategy for automated generalisation of the United States National Hydrography Dataset*, 11th ICA Workshop on Generalisation and Multiple Representation, Montpellier, France.

Stanislawski, L.V. 2009. Feature pruning by upstream drainage area to support automated generalization of the United States National Hydrography Dataset. *Computers, Environment and Urban Systems* 33(5): 325-333.

Stanislawski, L.V. and B.P. Buttenfield. 2010. Hydrographic Feature Generalization in Dry Mountainous Terrain. In: *Proceedings of AutoCarto 2010*, Orlando, Florida.

Stanislawski. L.V. and B.P. Buttenfield (forthcoming). A Raster Alternative for Partitioning Line Densities to Support Automated Cartographic Generalization. In: *Proceedings of the 25th International Cartography Conference 2011*, Paris, France.

Stanislawski, L.V. and M. Finn. 2010. Integrating Hydrographic Generalization over Multiple Physiographic Regimes. In: *Proceedings of the Generalization and Data Integration (GDI 2010) Symposium*, Boulder, Colorado (forthcoming).

Stanislawski, L.V., B.P. Buttenfield and V.A. Samaranayake. 2010. *Automated Metric Assessment of Hydrographic Feature Generalization through Bootstrapping*. 12th ICA Workshop on Generalization and Multiple Representations, Zurich, Switzerland.

Stanislawski, L.V., B.P. Buttenfield, M.P Finn and K. Roth. 2009. Stratified Database Pruning to Support Local Density Variations in Automated Generalization of the United States National Hydrography Dataset. In: *Proceedings of the 24th International Cartography Conference*, Santiago, Chile.

Stanislawski, L.V, M. Finn, E.L. Usery and M. Barnes, M. 2007. Assessment of a Rapid Approach for Estimating Catchment Areas for Surface Drainage Lines. In: *Proceedings of the ACSM-IPLSA-MSPS*, St. Louis Missouri.

Stanislawski, L.V., M. Finn, M. Starbuck, E.L. Usery and P. Turley. 2006. Estimation of Accumulated Upstream Drainage Values in Braided Streams Using Augmented Directed Graphs. In: *Proceedings of AutoCarto 2006*, Vancouver, Washington.

Stroh, W.J., S.J. Butzler and C.A. Brewer. 2010. Establishing Classification and Hierarchy in Populated Place Labeling for Multiscale Mapping for The National Map. In: *Proceedings of AutoCarto 2010*, Orlando FL (CD-ROM in production).

Sugarbaker, L., K. Coray and B. Poore. 2009. *The National Map Customer Requirements: Findings from Interviews and Surveys*. USGS Open-File Report 2009-1222.

Usery, E.L., M.P. Finn and M. Starbuck. 2009a. Data Layer Integration for *The National Map* of The United States. *Cartographic Perspectives* 6: 28-41.

US. Census 2007. *North America Industry Classification System*, U.S. Census Bureau, *http://www.census.gov/eos/www/nacis/*(accessed September 2010).

Usery, E.L., J. Choi and M.P. Finn, 2009b. Modeling Sea-level Rise and Surge in Low-lying Urban Areas using Spatial Data, Geographic Information Systems, and Animation Methods. In P. Showalter and Y. Lu (eds.), *Geospatial Techniques in Urban Hazard and Disaster Analysis*, Springer, Dordrecht, pp. 11-20.

Varanka, D. 2009. A Topographic Feature Taxonomy for a U.S. National Topographic Mapping Ontology, In: *Proceedings of the International Cartography Conference*, Santiago, Chile.

Varanka, D. and E.L. Usery. 2010. Introduction to the Special Section, Ontological Issues for *The National Map*. *Cartographica* 45(2): 103-104.

Varanka, D., J. Carter, T. Shoberg and E.L. Usery. 2010. Topographic Mapping Data Semantics: Data Conversion and Enhancement. Book Chapter submitted to A. Sheth and N. Ashish (eds.), *Geospatial Semantics*, Springer series on Semantic Web and Beyond: Computing for Human Experience.

Varanka, D. and T. Jerris. 2010. Ontology Design Patterns for Complex Topographic Features. In: *Proceedings of AutoCarto 2010*, Orlando FL, Nov.

Williams, M. S., M. P. Finn and R. A. Buehler. 2006. *An Open Source, Object-Oriented General Cartographic Transformation Program (GCTP)*. Paper presented at the International Society for Photogrammetry and Remote Sensing Commission IV Symposium on Geospatial Databases for Sustainable Development, Goa, India.

Wilmer, J.M. and C. A. Brewer. 2010. Application of the Radical Law in Generalization of National Hydrography Data for Multi-Scale Mapping. In: *Proceedings of AutoCarto 2010*,

Orlando FL (CD-ROM).
Wilson, M. and B. Poore. 2009. Repositioning Critical GIS. *Cartographica* 44(1).

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Transitions in Digital Map Production: An Industry Perspective

Jon Thies and Vince Smith

Introduction

Applications for the use and production of maps have evolved significantly in the past decades, especially in the transition of static paper maps to digital on-line maps. This is especially evident when evaluating the requirements for digital map production and its subsequent digital map use. In 2007, the Chief Technology Officer at Intergraph Corporation predicted "a shift over the next five to ten years from the current paradigm of on-line dynamic mapping and other location-based information to a significant growth in real-time operational geospatial applications" (Batty 2007). This paradigm shift continues and can be illustrated by the expanded functional capabilities provided within internet mapping sites. The functional capabilities available on older web sites were generally restricted to basic map visualization and map navigation tasks. On newer web sites, the introduction of analytical capabilities is providing the end-user the ability to query the data, allowing them to ask the appropriate questions for their application, and thus providing them the ability to make real-time operational decisions.

The increasing availability of GPS, on-board navigation systems, and consumer internet mapping sites (Google Maps, Bing Maps) is changing people's perception of maps and increasing their expectations of digital cartographic products.

Traditional map producers such as government agencies and private mapping companies are beginning to provide a new generation of cartographic products based on the needs of their customers. The map user wants more options to meet their specific needs, and they want it in real time to assist them in their decision making, which is especially relevant in military, public safety, and natural disaster situations. To some extent, a portion of the map production responsibility is being passed on from the traditional map producer to the on-line map user.

Software vendors supporting the GIS industry recognize these trends and are responding by developing applications that leverage traditional map production capabilities to compliment and assist in the geospatial decision making process. These trends are also impacting the traditional map producer, expanding their role from map producer to digital data provider. For the map user to access data in real-time, the map producer must expand their product offerings to include raw geospatial data, instead of simply offering a finished cartographic product. This transition involves data sharing between the map producer and the map user, and will require all parties (map user, map producer, software vendor) to focus on:

- *Data standards*
- *Seamless enterprise databases*
- *Data modeling*

Data Standards

Data sharing and system interoperability requires the adoption of industry standards, many of which have been defined by assorted international bodies such as the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO). In some cases these standards have a legislative mandate, as is the case with the Infrastructure for Spatial Information in Europe (INSPIRE). Adopting

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these standards provides a common framework for data exchange between the requesting map user and the map producer providing the data. Map producers recognized the importance of adopting industry standards when they began providing digital files to their printer instead of films. Producing standard file formats such as Tag Image File Format for Image Technology (TIFF/IT[1]) and the Prepress Digital Exchange using PDF (PDF/X[2]) relieved much of their data exchange issues. Data exchange for map composition over the web needs to consider the dynamic aspect of requesting and delivering data in real-time. This has spawned an assortment of standards such as Web Coverage Service (WCS[3]), Web Feature Service (WFS[4]), Web Map Service (WMS[5]) and their associated data file formats such as Geography Markup Language (GML[6]), and Keyhole Markup Language (KML[7]).

Seamless Enterprise Databases

During the initial transition from paper to digital maps, it was logical for map producers to store their data in separate physical databases based on their printing requirements. While this data storage model may have served the purpose of supporting traditional lithographic workflows, it often introduced data redundancy and imposed unnecessary limitations on the data. The map producer's long-term goal was to be able to produce multiple products from a single database, which requires a more unified data storage model. This prompted many map producers to combine the separate physical databases into a seamless enterprise database that could be used as the basis for constructing multiple cartographic products independent of traditional sheet limits, e.g. geographic quadrangles or regional extents. A seamless database is even more important today as map producers begin sharing their data via the web and provides additional flexibility for the end-user when selecting their particular area of interest. This also facilitates the storage of a multi-representation database (MRDB) where different views of the data can be provided based on map scale ranges.

Data Modeling

The type of map content made available for data sharing is determined in part by the business focus of the map producer providing the data, e.g. cadastral or transportation. Larger organizations may maintain and distribute multiple representations of the same data to support the production of cartographic products at different map scales. Data transformations of a large scale representation may include model generalization, cartographic generalization, or complete schema remodeling in order to produce a corresponding small scale representation. Any data modeling/remodeling employed by the map producer to facilitate data sharing must include data validation for geometry, topology, features, and attributes to ensure that the data provided conforms to acceptable levels of accuracy, completeness, and currency. In addition to providing the raw geospatial data, the map producer must also provide geospatial metadata to assist map users determine whether or not the requested data is suitable for their application. For example, the metadata may include information describing the date, scale, and method used for the initial data collection.

Conclusion

Technological advancements supporting the storage, delivery, and presentation of geospatial data continue to have a significant impact on digital map production. These advancements directly correlate to the sophistication of the available on-line cartographic products found in the market today. Irrespective of these advancements, the end user must have confidence in the digital content provided to them by the map producer / data provider to

[1]Tag Image File Format for Image Technology (TIFF/IT) is ISO 12639.
[2]Prepress Digital Exchange using PDF (PDF/X) is ISO 15930 and includes multiple PDF/X standards.
[3]Web Coverage Service (WCS) Implementation Standard is OGC 07-067r5.
[4]OpenGIS Web Feature Service (WFS) Implementation Specification is OGC 04-094.
[5]OpenGIS Web Map Service (WMS) Implementation Specification is OGC 06-042.
[6]OpenGIS Geography Markup Language (GML) Encoding Standard is OGC and ISO 19136.
[7]OGC KML Encoding Standard is OGC 07-147r2.

ensure acceptable levels of quality and accuracy. This confidence is critical in the geospatial decision making process.

REFERENCES

Batty, P. 2007. Cartography 2007: Reflection, Status, and Prediction (Preface). *Cartography and Geographic Information Science* 34(2)

Leitner, M. and A. Skupin. 2007. *Cartography 2007: Reflection, Status, and Prediction* (Preface). A collection of submissions to the 2007 U.S. National Report to the International Cartographic Association. Online: *http://www.cartogis.org/docs/journal/2007_abstracts.pdf.*

ISO 12639:2004. Graphic technology – Prepress digital data exchange – Tag image file format for image technology (TIFF/IT), from *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=34342*.

ISO 15930-6:2003. Graphic technology – Prepress digital data exchange using PDF – Part 6: Complete exchange of printing data suitable for colour-managed workflows using PDF 1.4 (PDF/X-3), from *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=39940*.

OGC 07-067r5. Web Coverage Service (WCS) Implementation Standard, from *http://www.opengeospatial.org/standards/wcs.*

OGC 04-094. OpenGIS Web Feature Service (WFS) Implementation Specification, from *http://www.opengeospatial.org/standards/wfs.*

OGC 06-042. OpenGIS Web Map Service (WMS) Implementation Specification, from *http://www.opengeospatial.org/standards/wms.*

OGC 07-036. OpenGIS Geography Markup Language (GML) Encoding Standard, from *http://www.opengeospatial.org/standards/gml.*

ISO 19136:2007. Geographic Information – Geography Markup Language (GML), from *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32554.*

OGC 07-147r2. OGC KML Encoding Standard, from *http://www.opengeospatial.org/standards/kml.*

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A Cadastral Geodatabase for the U.S. Fish and Wildlife Service

Douglas L. Vandegraft

ABSTRACT: The U.S. Fish & Wildlife Service Cadastral Data Working Group, comprised of cartographers and GIS specialists from all management regions, has produced a state-of-the-art database that stores data for all interests in real property in the U.S. National Wildlife Refuge System. The FWS Cadastral Geodatabase provides an integral component of the Refuge Lands Geographic Information System (RLGIS) by supplying boundary and parcel information to the biological geodatabases currently within the RLGIS data model. Cadastral data describes the past, current, and future right, title and interest in real property, including the spatial information necessary to describe the geographic extent. The geodatabase is the common data storage format for geographic features and attributes. A consistent and accurate cadastral geodatabase that is common across the nation and can be shared between management regions enables users to leverage the spatial data to its full potential. A web mapping application has been built utilizing the FWS cadastral geodatabase, allowing a non-GIS user to view the FWS managed lands and waters.

KEYWORDS: cadastral, geodatabase, refuge lands, geographic information system

Introduction

The U.S. Fish & Wildlife Service (FWS), a Federal bureau within the Department of the Interior (DOI), has been using geographic information system (GIS) technology since the mid-1980's to map lands and waters for which they have management responsibility. This includes the National Wildlife Refuge System (NWRS), which consists of over 150 million acres located within 552 wildlife refuges (2010). The FWS manages these lands and waters through a regime of eight geographic Regions, defined primarily by State boundaries and physical geography (i.e. Region 3 is the Midwest Region). While much of the day-to-day management of FWS lands occurs from Field Stations located near a particular wildlife refuge or other FWS property, most of the decisions affecting the entire Region are made from a designated Regional Office located in a major city within the Region. Primary mapping capabilities are also found in these Regional Offices. The responsibility for mapping the "land status" (cadastral) information for FWS lands has historically been assigned to the FWS Division of Realty.

The Division of Realty has maintained land status maps in a standardized fashion since the 1940's. Using traditional cartographic methods, the maps reflected the NWRS, national fish hatcheries, coordination (shared management) areas, and administrative sites.

In the 1980's, several of the Regional Offices began using the AutoCAD software for their mapping activities. AutoCAD, made by Autodesk Inc., was the first mapping software to be incorporated into the official FWS standards for the mapping of real property. As revised in 1995, the Maps chapter of the FWS manual directed that AutoCAD hatch patterns be used to display the various land status categories. It also prescribed the specific Rapidograph pen size to use for the many linetypes used on the Realty maps. The FWS was in desperate need of an upgrade in cartographic methodology.

Separate from the Maps chapter effort, a FWS GIS Steering Committee was formed in 1991. The Steering Committee consisted of one representative from each Region, and was chaired

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by the National Spatial Data Manager. In 1996, the Service Lands Spatial Data Guidelines Project was launched. An ad hoc subcommittee of the FWS GIS Steering Committee developed a Process Description for Creating and Managing Service Lands Boundary Digital Data (Standard Operating Procedure 97-01) document. The objective of SOP 97-01 was to "provide an accurate, documented and nationally consistent method for creating and updating a spatial data layer for National Wildlife Refuge boundary information." SOP 97-01 provided specific instructions for digitizing the Division of Realty land status maps. "Process 1" employed the Arc/Info software, made by the Environmental Systems Research Institute, Inc. (ESRI), and "Process 2" was for the AutoCAD software. The data digitized using AutoCAD was intended to be migrated to the Arc/Info coverage environment so that the refuge boundaries and individual land status polygons could be attributed.

The methodology and attribution scheme described in SOP 97-01 was adopted by all of the Regions, and led to the digitizing of all the external boundaries of the National Wildlife Refuges, and much of the internal land status. However, a complete dataset of digital boundaries of all of the refuges, combined with all of the parcels within those refuges, was never achieved.

In 2000, the Headquarters Office for the NWRS in Washington D.C. hired a Chief Cartographer (the author of this paper), who was given a primary charge of helping the Regions complete the digitizing of boundaries and land status within the NWRS. In 2002, a working group was formed with representatives from each Region to develop new mapping standards for the FWS that embraced GIS technological capabilities and streamlined the production of map products. Over the next three years, the Maps chapter of the FWS manual was completely rewritten, and a new standard for NWRS maps was adopted.

Meanwhile, ESRI engineers were developing the geodatabase architecture for ArcGIS. The era of a single-user GIS professional generating individual "coverages" and "shapefiles" and storing them on their personal computer was evolving into a multi-user environment where maps and data were being accessed via the internet and intranet.

In response to the ESRI product evolution, the same group of professionals who developed new standards for mapping the FWS lands and waters shifted focus towards the challenge of developing a geodatabase that would store and manage the FWS cadastral data, creating a spatial database for FWS cadastral data and a common boundary dataset for all Regions to utilize.

Cadastral Geodatabase Defined

The Cadastral Subcommittee of the Federal Geographic Data Committee, in their Cadastral Data Content Standard for the National Spatial Data Infrastructure (2002) document, defines cadastral data as "the geographic extent of the past, current, and future rights and interests in real property including the spatial information necessary to describe that geographic extent." The term "geodatabase" was invented by ESRI. The word implies geographic database which was probably the original intent. The actual definition, of which there are several from ESRI, states that a geodatabase is "[a]n ArcGIS data storage format... [and] represents geographic features and attributes as objects hosted inside a relational database management system that provides services for managing geographic data. These services include validation rules, relationships, and topological associations." The geodatabase is an object-oriented vector data model. In the geodatabase, entities are represented as objects with properties, behavior, and relationships. A variety of different object types, such as simple objects, geographic features (objects with a location), network features (objects with geometric integration with other features), and annotation features, can all reside and relate to each other within the geodatabase. The geodatabase model allows the user to define relationships between objects, together with rules for maintaining the referential integrity between the objects. ESRI first developed the "personal" geodatabase that was ideal for a single user or a small workgroup with smaller datasets. The development of the "file" geodatabase allowed large datasets to be stored and manipulated.

Refuge Land Geographic Information Systems (RLGIS)

In order to assist FWS managers and biologists in the collection, organization, and use of spatial data for their day-to-day management activities, RLGIS was developed. RLGIS is a geodatabase that was designed by FWS biologists and GIS specialists to aid in the development and implementation of biological programs. Field Station managers and wildlife biologists within the NWRS indicated a need to collect and manage spatial information in a consistent and effective manner. Based on the data requirements submitted by the field stations, GIS support staff within Regions 1 & 2 developed the data structures, protocols, and applications for creating spatial data, populating databases and managing the resulting information.

The RLGIS data model encompasses three geodatabases:

- Features, Management Units, and Monitoring (47 Feature Classes that include cultural resources, refuge facilities, and wildlife monitoring sites)
- Landcover and Habitat (10 Feature Classes describing historic land use, including inventories)
- Resource Management (15 Feature Classes that describe management of water, animal populations, and vegetation)

A critical component missing from the RLGIS was the cadastral layer. The same working group who wrote the new "Mapping" chapter of the FWS manual convened in October 2005 in Denver, CO, to begin the job of creating a cadastral geodatabase for use with the RLGIS, and ultimately for the entire FWS.

Designing a Cadastral Geodatabase for the FWS

The working group, now calling itself the "Cadastral Data Working Group" (CDWG), agreed that they were working to assemble a geodatabase model that would be common to all Regions and could be combined ("rolled-up") to represent all of the FWS lands and waters. Further, the Regions would be responsible for populating and maintaining a specific version of the geodatabase assigned exclusively to their Region. While additional feature classes, fields, and domains could be added to a Regional version, all of the Regions would maintain a national version that would remain intact with the common, agreed upon core features, fields and domains.

There were many challenges to this effort. While a cadastral geodatabase had already been created for the Alaska region, it was specific to the unique land status situation there (i.e. lands reserved for Native Alaskans; lands allotted to the state via the Statehood Act). Even though SOP 97-01 had identified common attributes, some of the regions hade made little progress towards digitizing refuge boundaries, and others had not digitized any parcels. While the Chief Cartographer was charged with organizing the project, the position carries no supervisory authority. This meant that cartographic/GIS needs of a region would often compete with the time needed for the project.

A primary goal of the FWS is to acquire land and water areas for the protection of wildlife habitats. Historically, wildlife refuges have

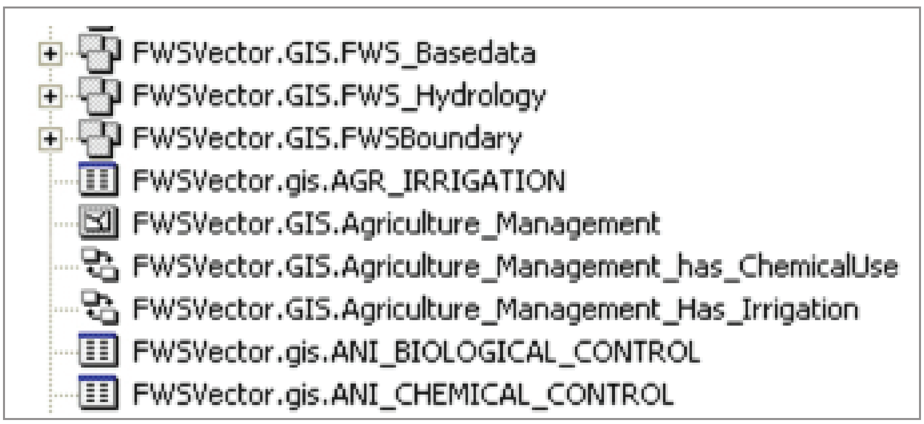


Figure 1. Sample data layers from the Refuge Lands GIS (RLGIS) geodatabase as viewed in ArcCatalog.

been created by a variety of legal actions, from Executive Orders issued by the President, to the donation of lands by a person or group. Since the 1970's, FWS biologists from the Division of Planning have identified lands or waters that are deemed valuable as habitat for an animal, bird, fish, or plant species. Boundary lines are drawn on maps identifying the valuable habitat areas, and an extensive process begins to approve the areas for inclusion within the NWRS. When the creation of a wildlife refuge is approved, the process of acquiring lands within the approved boundary begins. The FWS has a policy of acquiring lands only from willing sellers.

There are two basic types of boundaries associated with a wildlife refuge:

- *Approved Acquisition* boundary: the line(s) enclosing those lands that the FWS has authority to acquire, in whole or in part. This boundary often encompasses both public and private land, but does not imply that all private parcels within the boundary are targeted for FWS acquisition.
- *Interest* boundary: the line(s) enclosing those lands for which the FWS has fee (primary, full ownership) or less than fee interest (secondary, such as a "conservation easement"). Where the FWS has the primary interest in the land or water, management responsibility is implied.

On FWS maps, individual parcels of land or water areas are identified by a "Tract Boundary" and "Tract Number." A "Status Map" depicts the tracts of land or water on which the FWS has acquired a property interest. An "Ownership Map" also depicts inholdings, which are lands within the approved acquisition boundary for which the FWS has yet to acquire an interest. Inholdings may be identified by tract boundary and tract number in addition to all of the information found on a Status Map.

In addition to inholdings, the FWS may issue a permit for a specific land use, such as sand or gravel extraction. The FWS also allows an easement or a right-of-way to a private party, such as for a road or trail. These equate to an encumbrance on lands managed by the FWS.

There are lands within FWS managed areas that have been designated by Congress as "wilderness", and rivers that have been designated as "wild and scenic." These types of special designations bring additional regulations and affect how the FWS manages the area.

In the contiguous 48 states, the perimeter for all the approved acquisition boundaries is approximately 1,671,010 kilometers (1,038,318 miles). While many of these boundary lines can be described using the Public Land Survey System, less than half of these boundary lines have been surveyed and platted by a professional land surveyor. It was decided that to reflect the accuracy of the line features, it would be imperative to show where survey monuments have been set along these lines.

Several specific entities combine to create the geodatabase:

- *Feature Class*: a collection of geographic features with the same geometry type (such as a point, line, or polygon), the same attributes, and the same spatial reference. Feature classes were created for the different boundary types, the parcels within those boundaries, and the survey monuments.
- *Feature Dataset*: a collection of Feature Classes stored together that share the same spatial reference, meaning that they have the same coordinate system and they are located within a common geographic area. The regional geodatabases, maintained by the regional cartographers, comprise the feature datasets.
- *Field*: a vertical column in a table containing numbers or words that further describe the feature class. Within the FWS geodatabase are many "common" fields, as well as "unique" fields that allow the cadastral data to be specifically identified and classified.
- *Domain*: The range of values allowed for entities in the field within the feature class. Within the FWS geodatabase, an alphanumeric system in a series of windows with pick-lists ensures consistent regional input.
- *Topology* is the term used to describe the rules and behavior used to manage the feature classes. Topology controls the editing tools and helps to maintain integrity of the data. The geodatabase evaluates the data against the topologic rules during a validation process. Any violations to the topologic rules are identified as errors, which can be corrected or

identified as exceptions to the rules. Topologic rules within the FWS geodatabase include the usual "must not overlap" and "must not have gaps" for polygons. However, with just a few exceptions, FWS-Interest must be covered by FWS-Approved. Tract-Boundary must be covered by boundary of FWS-Interest, and FWS-Encumbrance must be covered by FWS-Interest: Acquired.

See Appendix for full list of Feature Classes, Fields, and Domains.

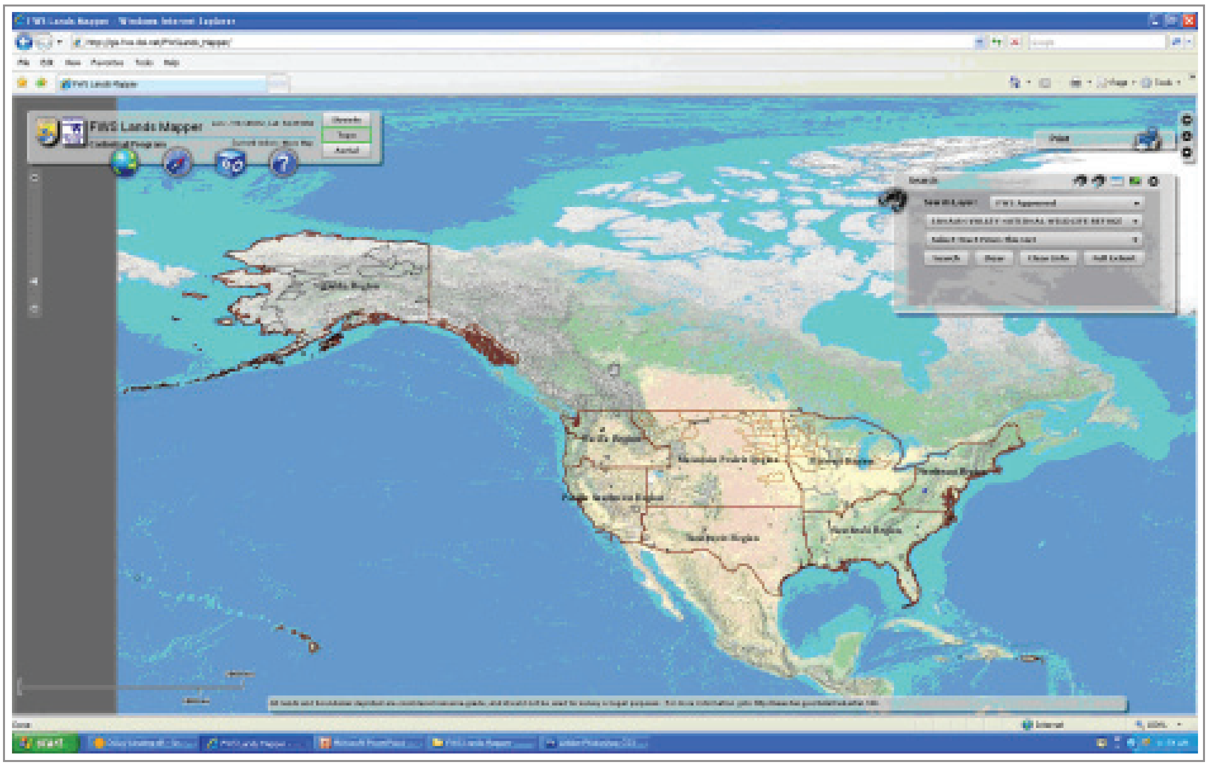
A Major Milestone

In August of 2008, the CDWG completed the population of the "FWSInterest" and "FWSApproved" feature classes. For the first time ever, all of the digitized National Wildlife Refuge boundaries and all of the parcels within those boundaries were in a common dataset. The other feature classes will continue to be populated, meaning that the cadastral geodatabase will grow in terms of size and usefulness. FWS is currently (2011) the only bureau within the Department of the Interior to have an accurate geospatial accounting of all the land and water it administers. The CDWG immediately began work on a "User's Manual" so that the processes of populating the geodatabase with cadastral data are documented. The User's Manual provides specific instructions for updating and maintaining the cadastral geodatabase.

The *FWS Lands Mapper*

A web mapping application using the FWS cadastral data was launched in December 2009. The "FWS Lands Mapper" was built on the Adobe Flex framework coupled with base data layers and tools directly from the ESRI "ArcGIS Online" web service. The FWS Lands Mapper allows the user to display the cadastral data over seamless aerial photography, topographic maps, or World Street Map data. Users can search and zoom to all FWS managed lands; locate acreage info and the associated websites for every National Wildlife Refuge; compute measurements of distance and area; and print or export custom-made maps. In addition to the attributes from the cadastral geodatabase, tabular data specific to the tracts of land and water is provided by the FWS Lands Record System (LRS). Although the FWS Lands Mapper is currently available only to FWS employees, a public ver-

Figure 2. User interface for the FWS cadastral data web mapping application.



sion is planned for launching in late 2011.

The FWS National Cadastral Data webpage URL is *http://www.fws.gov/GIS/data/CadastralDB/index.htm.*

The Approved Acquisition boundaries, FWS Interest, and Special Designations feature classes are available for download. The data is also available as a MapServer, so that the viewer can readily import the data into ArcMap, ArcGIS Explorer, Google Earth, and as ArcGIS Java Script.

REFERENCES

Environmental Systems Research Institute Inc. 2007. *An Overview of Distributing Data with Geodatabases*. ESRI Technical Paper No. 34131, *http://www.esri.com*.

Environmental Systems Research Institute Inc. 2001. *Dictionary of GIS Terminology*, ESRI Press

Federal Geographic Data Committee Cadastral Subcommittee. 2003. FGDC Cadastral Data Content Standard version 1.3, Online: *http://www.nationalcad.org/showdoclist*.

U.S. Fish and Wildlife Service. 1998. *Process Description for Creating and Managing Service Lands Boundary Digital Data* (Draft SOP 97-01) Online: *http://www.fws.gov/data/gissop.html.*

U.S. Fish and Wildlife Service. 2008. *Refuge Land Geographic Information Systems (RLGIS) Data Model*, Online: *https://intranet.fws.gov/region9/refuges/rlgis/datamodel/overview.html.*

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APPENDIX

The CDWG has defined several feature classes to capture the primary cadastral features.

Polygon Features "FWSApproved"=FWS Approved Acquisition Boundary.

"AcqApproval" = Acquisition Approval. Describes the approval authority under which land has been or may be acquired.

"FWSInterest" = FWS Interest. FWS acquired tracts, fee title or less-than-fee title. Includes all FWS managed tracts.

"FWSEncumbrance" = FWS Encumbrance. Permits and outgrants issued by the FWS. Includes most easements and Rights-of-Way.

"SpecialDesignation" = Special Designation. Boundaries of wilderness areas and other special designations.

Point Features

"SurveyMonument" = Land Survey Monuments.

Line Features

"TractBoundary" = Tract Boundary. Linear feature attributes of FWSInterest tracts (polygons).

Within the Feature Classes are found specific "Fields" which add value and further describe the features. Several fields are common to all Feature Classes.

Common Fields

"IFWS" = DOI-FWS Number. A unique code assigned to each land or water area over which the FWS has some type of jurisdiction.

"LIT" = Literals. Unique alpha codes that identify the FWS lands or waters. Example: Petit Manan National Wildlife Refuge = PMN.

"ORGNAME" = official name of the organization. Example: Petit Manan National Wildlife Refuge.

"ORGCODE" = a unique five-digit numeric code assigned FWS organizations where personnel are assigned, including all unstaffed land management units.

"RSL_TYPE" = Organization Type. Administrative categories that identify FWS organizations by their primary function. Example: National Wildlife Refuge.

"CMPXNAME" = name of the management complex. Some units of the NWRS are managed together in a "complex" because they are located relatively close to each other. Example: Maine Coastal Islands National Wildlife Refuge Complex.

"FWSREGION" = FWS Region Number.

"GISACRES" = Geographic Information System Acres. The GIS-calculated acres contained within the approved acquisition boundary or tract boundary.

"DOCACRES" = Document Acres. Acres indicated in a deed or other official document.

"COMMENTS" = notes of relevance to the feature class.

The following are those Feature Classes that contain Fields that are not common to all Feature Classes.

Unique Fields

FWSApproved:

"MAXACRES" = maximum number of acres approved for acquisition within an approved acquisition boundary.

"APPTYPE" = subtype field that assigns the attributes: 0 for 'Inclusive' and 1 for 'Limited.' These attributes assign the limits of approval authority within the acquisition boundary.

AcqApproval:

"AUTHTYPE" = type of authority that approved the lands within the boundary for acquisition. Examples: Executive Order; Public Law.

"DATEAPPR" = date that the area was approved for acquisition.

FWSInterest:

"INTTYPE1" = Interest Type No. 1. The primary real property interest (land or water) held by the FWS.

"INTTYPE2" = Interest Type No. 2. The secondary real property interest (land or water) held by the FWS.

"INTIDNO" = internal identification number.

"STATUS" = subtype field that assigns the attributes: 0 for 'Acquired,' 1 for 'Inholding,' and 2 for 'Divested.'

FWSEncumbrance:

"ENCBTYPE" = type of encumbrance (easement, Right-of-Way, etc.)

"ISUDATE" = date the encumbrance was issued.

"EXPDATE" = date the encumbrance will expire.

"ENCBIDNO" = identification number of the encumbrance.

FWSInterest & FWSEncumbrance:

"DIVNAME" = name given to a FWS organizational division.

"UNITNAME" = name given to a FWS organizational unit.

"SUBNAME" = name given to a FWS organizational subunit.

"SURACRES" = number of acres determined by a land survey.

"TRACTNO" = alpha/numeric code assigned to a tract of land or water.

SpecialDesignation:

"DOCNAME" = name of the legal document creating the special designation.

"DESNAME" = name of the special designation.

"DESTYPE" = type of the special designation.

"DESDATE" = date that the special designation became effective.

"REACHMIL" = number of river reach miles within the special designation.

FWSInterest & SpecialDesignation:

"MGMTCODE" = management code to reflect the managing station of a particular unit.

SurveyMonument:

"DESIGNAT" = designation (specific purpose of the monument).

"TYPE" = specific type of monument (brass cap, iron rod, etc.).

"DESCRIPT" = description of monument (corner number).

"LOCATION" = location of monument (PLSS, latitude/longitude coordinates).

"SETBY" = who (agency, private firm) the monument was set by.

"SETYEAR" = year the monument was set.

"YEARFND" = year the monument was found/inspected.

"CONDITN" = condition of the monument.

"PROBLEM" = any known problem with the monument.

"PROBDESC" = further description of the problem.

TractBoundary:

"INTLCODE" = internal code number.

"RELICODE" = reliability code number (value pertaining to accuracy).

ApprType = Approval Type. Description of acquisition authority.

DesType = Designation Type. The type of Special Federal Designation.

IFWS = Internal FWS Number.

IntCode1 = Interest Code #1. The primary interest of the FWS.

IntCode2 = Interest Code #2. The secondary interest the FWS.

EncbType = Type of Encumbrance.

FWSReg = FWS Region name.

OrgCode = Organization Code.

OrgName = Organization Name.

RslType = Organization type.

Lit = Literal.

LinCodes = Line Codes. The codes represent the specific interest that exists on either side of the line.

RelCodes = Reliability Codes. The codes represent the accuracy of the line itself.

MonType = Monument Type.

SetMon = Set Monument. Who (firm or agency) set the land survey monument.

MonCond = Monument Condition. Actual condition of the land survey monument.

MonPyn = Monument Problem. Any known problem with the land survey monument.

Cartographic Support for the 2010 Decennial Census of the United States

Constance Beard, Michael DeGennaro and William Thompson

ABSTRACT: As this article is published, the U.S. Census Bureau is completing work for the twenty third decennial census of the United States. Once again, the MAF/TIGER system served as the geospatial infrastructure supporting numerous census operations and data collection, tabulation, and dissemination activities. From data collection to data dissemination we trace the recent activities of the 2010 Decennial Census of the United States to illustrate the role maps and geospatial data play in an increasing variety of public and private sector activities across the nation. To ensure a successful 2010 Census, millions of maps had to be created. This article will give an overview of the automated mapping system designed to create these maps. This includes a discussion about associated software needed and the variety of map types that were developed. Finally, future map production and geospatial activities at the Census Bureau will be discussed.

KEYWORDS: 2010 Census, TIGER, United States Census

Introduction

In the years between Census 2000 and 2010 Census, the Census Bureau conducted a major overhaul of its Master Address File/ Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) geographic database, which provides the spatial framework for all census activities. The key components of this initiative were to improve the spatial accuracy of the coordinates in TIGER to meet standards needed by current data gathering technology, including the use of GPS, to combine address information with spatial information in a single integrated database, and to convert MAF/ TIGER to a current commercial format in order to make the data more available to users inside and outside the Census Bureau, better integrate spatial and tabular data, and make the data more accessible to commercial software and common data processing languages.

The early, ambitious plans for 2010 Census envisioned a reduced role for paper maps. Census enumerators were to use a map-like visual display on hand-held computing devices for navigation and spatial data collection. However, when cost and technological issues made it necessary to limit the use of hand-held devices to only the address canvassing operation (where enumerators walked every street in the nation to verify the address list), the strategy for the remaining operations reverted back to the use of millions of paper map sheets by the enumerators to find their way and record spatial information. The volume of census maps required and the limited time available for the production ruled out anything but a totally automated system approach. The system should formalize and automate basic map design decisions such as map scale selection, multiple sheet map configuration, and feature label placement, as well as automating all interactions with the database and necessary geometric processing. However the MAF/TIGER data in its modernized form rendered the existing automated mapping software obsolete.

Census Bureau cartographers sought commercial mapping or GIS software to suit

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the need, but after several months of market research and testing, they determined that no commercial package had all the customization, data handling, and performance capabilities that were needed.

Therefore, a plan was developed to create a new mapping system in-house, with predominately new software, supplemented in key places by modules carried over from the Census 2000 mapping system and by some commercial software tools. The new system was referred to as the Census Automated Map Production System (CAMPS).

Automated Mapping at the U.S. Census Bureau

Cartographic Data for Mapping

At its core, MAF/TIGER is a seamless, transactional, national dataset of geospatial data and relationships, feature attributes, and complex rules of data interaction and behavior. The transactional database stores the primitive geometries: the points, lines, and areas with detailed attributes, that are needed to describe real world features such as roads, rivers, census blocks, census tracts, cities, and counties. It is designed and organized specifically for continual and simultaneous spatial updates of both individual manual changes and automated batch updates, from varied sources, such as census field workers or local government partners.

At least twice a year, all database transactions are paused to create a benchmark of MAF/TIGER. No updates are allowed on the MAF/TIGER benchmark. The benchmark is a stable snapshot-in-time of the most current MAF/TIGER data. Although stable, the data in the MAF/TIGER benchmark is still not conducive for mapping. This primitive data is highly fragmented, overly detailed, and under classified for suitable cartographic rendering. Many features and geographic entities have not yet been built with geometries and attributes conducive to a pleasing, clear, and functional cartographic display. Also, it is often necessary to merge or generalize features or create additional classes of existing features to meet the symbolization requirements for automated map creation.

To meet mapping needs, it was necessary to build an additional database that served as an extension to the MAF/TIGER benchmark. The processes that create this Cartographic Database link MAF/TIGER benchmark primitives to build high level real world features such as roads, rails, hydrography, and geographic areas along with their associated names. Geographic area relationships and hierarchies are calculated that can be used to optimize boundary symbolization. Features are classified and categorized to facilitate organized, aesthetic, intuitive symbolization.

Census Automated Map Production System (CAMPS)

Like its predecessor systems used in the 1990 and 2000 censuses, CAMPS is a system for the batch creation of static maps, whether in paper or electronic format. CAMPS maps are always based on a geographic entity like a city, county, census block, or data collection assignment area. Although many CAMPS projects map the entire United States, they do so on an entity-by-entity basis rather than mapping the entire nation as a single series of map sheets at the same scale. Symbolization and content are constant throughout the project, but map scale and sheeting decisions are based on the characteristics of each entity to be mapped. Before production begins, census cartographers develop, test, and deploy parameterized instructions to CAMPS regarding symbolization, content, and layout. Other parameters guide CAMPS in the steps involved in scale selection, sheet configuration of a multiple-sheet map, and feature label placement. CAMPS also can create inset maps, if, after analysis of features at the selected scale, areas of unacceptably dense features are found. Those areas are mapped on separate sheets at larger scales than the rest of the map. The sheet configuration routine can create several configurations to compare and select the one that strikes the best balance of economy of map sheets and legible scale.

Much of the cartographic intelligence built into CAMPS' scaling, sheet configuration, and quality assurance routines is based on the fact that the legibility of feature name text is crucial to a quality map. CAMPS utilizes an enhanced version of the same automated text placement engine that was used to make Census 2000 maps. The CAMPS text placement software allows the cartographer to designate a set of placement instructions for each feature class. When attempting to label a feature, the software follows the set of instructions with consideration for text conflict, alternative placement options such as angle, leadering, and stacking, and text characteristics such as size.

CAMPS collects a whole host of production and map specific metadata and incorporates quality checks on the completed map to assure that it is within prescribed parameters for scale, number of sheets, and content. This emphasis on internal automated map quality review is an enhancement over previous census mapping systems.

This modularized, parameter driven, CAMPS system provided the flexibility needed to create map products tailored to operational needs. To make this happen, cartographers worked closely with Census Bureau and Partnership customers to clearly define and prototype a map design to meet user, operation, and production requirements. The process of collaborative dialogue supported by prototype graphics worked well to meet our primary objective, to optimize map designs to meet customized requirements with the fewest number of products and the smallest possible resource consumption.

The CAMPS system became operational in the fall of 2007 and began creating maps for the Census Dress Rehearsal of 2008 and for the early 2010 Census operations. Peak map production for the census came in the summer and fall of 2009, when maps to support many of the data collection field operations needed to be created.

One System - Multiple Map Types

To support field data collections operations, Census cartographers designed and produced numerous distinct map types. These included plotted large format wall-sized maps of administrative areas, and small format page-size maps that were printed and assembled into enumerator map packages for all 6.8 million census collection block entities.

Large format maps were an invaluable reference to the administrative areas for the various census operations and as a tool for hiring and assigning enumerator casework in Headquarters, the Regional Offices, and Local Census Offices (LCO). These full color reference maps fell into two basic categories. General support maps included reference maps for individual LCOs, maps that assigned geocoding locations for administrative use, and regional and national reference maps displaying the hierarchy of census unit boundaries. Field operation specific maps included those showing subdivisions of LCOs, including Field Office Supervisory Districts, Crew Leader Districts, and Enumeration Assignment Areas.

Small format, 11 by 17 inch maps were used by the enumerator in the field as a reference to locate their casework assignment area and as a base map for feature and manual address updates (see Figure 1). Three distinct types of black and white maps – “assignment locator,” “assignment area,” and “collection block” maps, were designed to be utilized as a package to complete the work assignments in the field.

The mapping system also produced numerous other map types to support the 2010 Census data collection operations. Since the behavior of the mapping system’s functional components were parameter driven, the same system could produce quality output for almost any map design.

Additionally, the system produced the annual Boundary and Annexation Survey map suite which was designed as an annotation product on which jurisdictions could draw geographic area boundary updates for digitizing and update into the TIGER database. Other similar, but distinct, map types were created for partnership programs with States and Tribal partners to define and delineate statistical area boundaries for which eventual 2010 Census data would be tabulated. The system also generated map products to support the Local Update of Census Addresses program prior to the census. These large scale, large format maps served as reference materials for local jurisdictions to verify housing unit counts and to provide important boundary and feature updates for their jurisdiction in time for census operations.

The flexibility of the system will be put to good use again as map design and production shift to publication quality products supporting congressional redistricting and the 2010 Census data dissemination (see Figure 2).

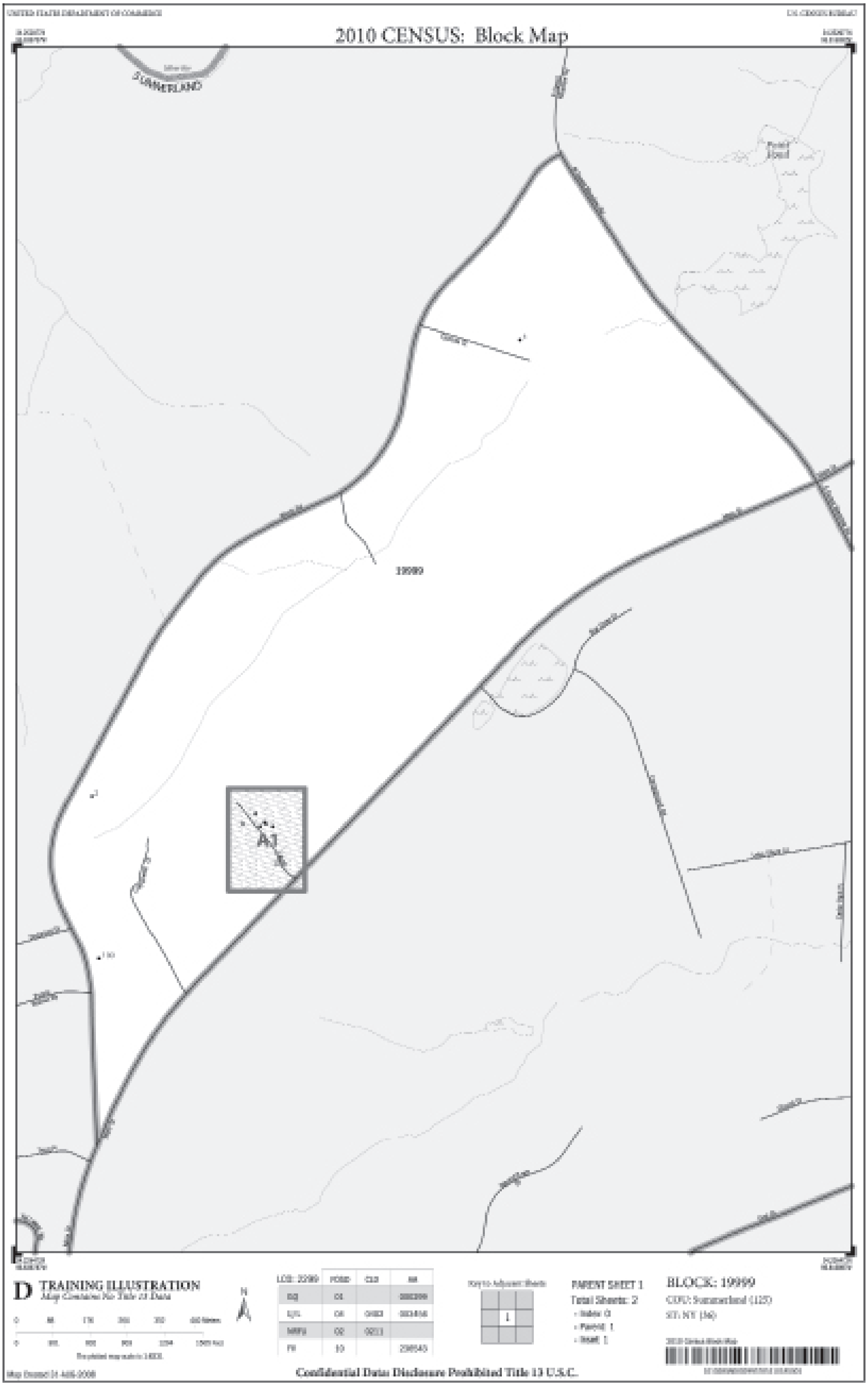

Figure 1. 2010 Census: Block-based Map for Enumeration (small format).

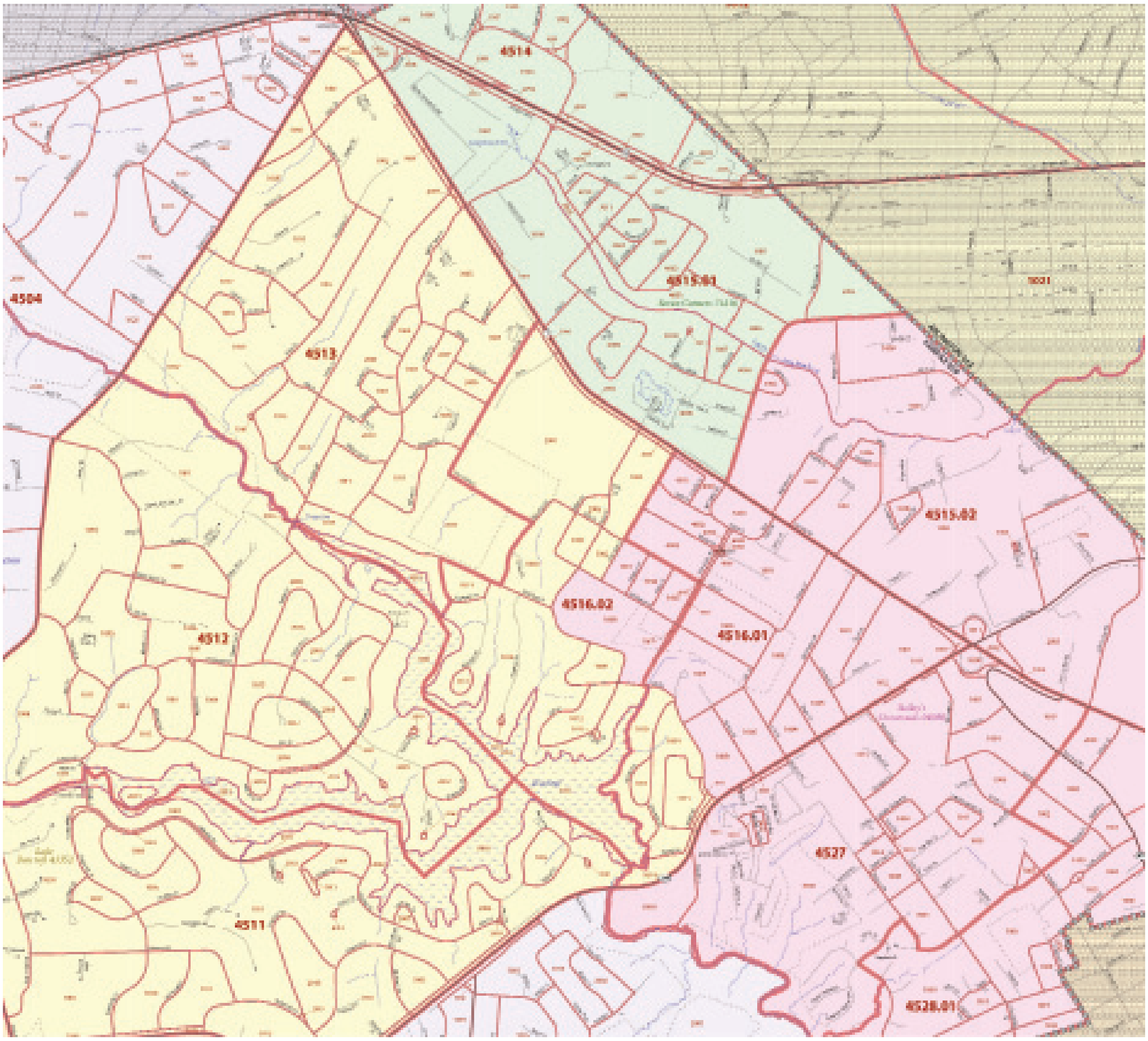

Figure 2: Excerpt from Census Block Map (large format).

Challenges and Goals in Census Map Design

Map design for the variety of public products differs from that for census operations. A more polished aesthetic is desirable in terms of format and text placement. As internet access expands, there is more demand for digital products. Experiences demonstrate it can be challenging to implement a map design that works just as well when viewed on screen as it does when printed on paper. As internet and relational database technology advances and data users have a growing desire to work with census geographic and demographic data in new and innovative ways, it is necessary for the Census Bureau to provide our data to users beyond traditional means. Existing web services such as the American FactFinder website are being redesigned to enhance performance and extend user interaction for the deployment of 2010 Census data and a number of new internet-based applications are in development for geospatial data distribution, data exploration, and map creation. The goal of these new applications is to meet the needs of the evolving cartography and Geographic Information System landscape by providing intuitive and streamlined methods for users to access and work with our data in addition to the more traditional dissemination methods.

One goal for the Census Bureau is to make our very large datasets easier for people to use by providing our geographic data as an online service that users can access and incorporate into their own projects, in conjunction with non-census data. For many users, this would alleviate the need to download or store census data locally and help ensure that they have the most up-to-date data. To allow users to explore TIGER data and perform basic demographic data analysis functions without having to load the data into their own GIS, online tools are being developed specifically for on-the-fly querying, analysis, and rendering. Such services could accelerate the time it takes to perform simple tasks and make this type of data analysis and exploration more accessible to the general public. Additionally, the plan is to provide to census data users a high-end, online, interactive thematic and reference mapping application service. This application will allow users to quickly create and output publication quality maps, using map templates designed by census cartographers, without having to worry about complicated symbology, text placement, and map design issues.

Conclusion

The Census Bureau will continue to develop and produce high quality cartographic and geographic products to support and augment censuses and surveys. The Census Bureau plans to continue its role as a trustworthy custodian of precise and accurate spatial feature and geographic area boundary data that is the critical infrastructure to the nation's statistical and GIS ventures. We will expand our web presence for product dissemination and spatial data access. We will incorporate appropriate new technologies such as geo-referencing into our products to enhance usability. We will explore the opportunities that burgeoning social media forums offer for data validation and acquisition without jeopardizing the security of our data and systems. And in our tradition, the Census Bureau will remain at the forefront of cartographic innovation.

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Note: This article reports the results of work undertaken by U.S. Census Bureau staff with the intent to inform and encourage discussion. Any views expressed are those of the author(s) and not necessarily those of the U.S. Census Bureau.

The U.S. Geological Survey Mapping and Cartographic Database Activities, 2006 – 2010

Kari J. Craun, John P. Donnelly and Gregory J. Allord

Introduction

The U.S. Geological Survey (USGS) began systematic topographic mapping of the United States in the 1880s, beginning with scales of 1:250,000 and 1:125,000 in support of geological mapping. Responding to the need for higher resolution and more detail, the 1:62,500-scale, 15-minute, topographic map series was begun in the beginning of the 20th century. Finally, in the 1950s the USGS adopted the 1:24,000-scale, 7.5-minute topographic map series to portray even more detail, completing the coverage of the conterminous 48 states of the United States with this series in 1992. In 2001, the USGS developed the vision and concept of *The National Map*, a topographic database for the 21st century and the source for a new generation of topographic maps (*http://nationalmap.gov/*). In 2008, the initial production of those maps began with a 1:24,000-scale digital product. In a separate, but related project, the USGS began scanning the existing inventory of historical topographic maps at all scales to accompany the new topographic maps. The USGS also had developed a digital database of *The National Atlas of the United States*. The digital version of Atlas is now Web-available and supports a mapping engine for small scale maps of the United States and North America. These three efforts define topographic mapping activities of the USGS during the last few years and are discussed below.

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Creating the Next Generation of USGS Topographic Maps, US Topo

In 2010, during the 125th anniversary of the initial Congressional authorization of funds for systematic topographic mapping, the USGS is in its second year of a 3-year cycle to produce the nation's next generation of topographic maps, US Topo. The US Topo program began in November 2008 as the USGS embarked on a program to create an updated series of topographic maps derived from *The National Map* databases. At the time of the US Topo program's inception, the United States Department of Agriculture's (USDA) National Aerial Imagery Program (NAIP) was following a 3-year cycle of acquisition of 1-meter or better orthorectified imagery for the continental United States (U.S. Department of Agriculture, 2010). Since one of the key layers to be included in the next generation mapping product is an orthorectified image, program leaders decided to aim for a 3-year update cycle for the US Topo products following the NAIP cycle of acquisition. Each year, the USGS will create updated map products for one-third of the nation's approximately 55,000, 7.5-minute quadrangle, primary scale series products. Thus, roughly 18,333 maps need to be produced each year to meet the program's goals. The content of the product is derived from *The National Map* databases, with the addition of the NAIP imagery. The process is automated, with a minimum of data editing at the time of product creation. The fundamental assumption with this process is that the acquisition and maintenance of the data are performed before the addition of the information to the map product. The feature content initially was minimal with the gradual addition of features as data become available and of sufficient quality to add to the map products. The goal of the program is to eventually reach the same level of feature content as included on a traditional USGS topographic map product. This is dependent on the availability and quality of the data sources.

The First Year of The US Topo Program: "Digital Map-Beta"

The first year of the 3-year cycle beginning in late 2008 was a ramp-up year in many respects for this program. The initial product, called Digital Map-Beta, contained limited content, as described in U.S. Geological Survey (2009), including:

- a NAIP orthorectified image; typically 1-2 meter ground sample distance, leaf-on, preferably current to within 3 years, preferably true color;
- Interstate and Federal highways, state routes, local roads in urban areas where cartographic considerations permit, all available roads in rural areas. Note that in 2009, the primary source for roads was the U.S. Census Bureau;
- airport names from the Geographic Names Information System (GNIS);
- geographic features and populated places from GNIS as cartographic considerations permit;
- names of hydrographic features from the National Hydrography Dataset (NHD);
- national boundaries;
- map collar and grids, including a 1,000-meter Universal Transverse Mercator (UTM) grid drawn and labeled in conformance with the U.S. National Grid (USNG) standard, corner coordinate labels and 2.5-minute grid ticks and labels, State Plane Coordinate System grid ticks; and
- Federal Geographic Data Committee (FGDC) compliant XML-formatted metadata.

With the GeoPDF format, users with freely available Adobe® Reader® software are able to view, print, and perform simple geographic information system-like functions using the product.

The goal for the first year of the program was to complete one-third of the continental United States with the "Digital Map-Beta" product, with a slight reduction in the goal because of the late start of the program in the production year. The states to be completed in fiscal year 2009 (October 2008 to September 2009) are shown in figure 1 in yellow.

The gray areas in these states are managed by the United States Department of Agriculture (USDA) Forest Service (USFS). The USGS maintains an agreement with USFS to show only USFS roads over their lands. During 2009, the two agencies worked to devise a plan to add USFS roads to USGS map products in these areas; however, the process was not mature enough to add these roads during the first year of the program. Thus, the USGS did not produce products over USFS lands in 2009, but chose to defer production in those areas until USFS roads could be shown.

Because of significant start-up issues related to large volume production of Digital Map-Beta products, the goal of completing one-third of the continental United States was not met in 2009. The USGS was, however, successful in producing 13,200 of these products and making them available for free download through the USGS Map Store at *http://store.usgs.gov* by

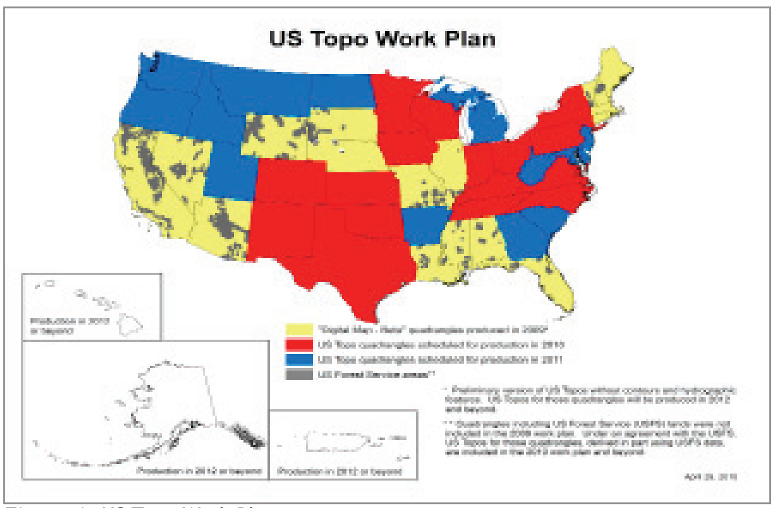

Figure 1. US Topo Work Plan.

September 30, 2009.

The Launch of the US Topo Product

During the second year of the US Topo program, significant feature content was added to the product. Most notably, contour lines and labels were added to depict the shape of the terrain. These contour lines were generated by software using source data from the National Elevation Dataset (NED) (U.S. Geological Survey, 2006). Hydrography or surface-water features from the National Hydrography Dataset (NHD) (U.S. Geological Survey, 2010) were also added to the US Topo feature set. Both the NED and the NHD are databases within *The National Map* that were derived in large part from the original published topographic maps. An example of a US Topo product with the orthoimage layer visible (top) and not visible (bottom), thus allowing surface-water and contour features to be easily viewed is shown in figure 2. Another notable change to the product in 2010 was the switch to a commercial roads data source in the latter part of the production year. In addition, the USGS began adding USFS roads to the product within National Forest boundaries (Moore, et al., 2009).

States that were planned for production in 2010 are shown in figure 1 in red. The products that remained in the 2009 production plan at the end of the year were added to the 2010 production goal for a total goal of 20,380, 7.5-minute US Topo products needed to complete the second year of the 3-year cycle. As of the writing of this paper (August 26, 2010), 15,800 US Topo products had been completed and made available at no cost for download through the USGS Map Store. The rate of increase in this total was approximately 150 per day.

Figure 2. Portion of the Hollidaysburg, PA US Topo product with the image layer on (left) and off (right).

The Third Year of the US Topo Cycle

Plans for 2011, the third year of the US Topo cycle, are to complete first-time coverage of the continental United States. Additional feature content will be added to the product during the course of the year, to include additional administrative boundaries; woodland and urban land cover layers; and some point-based man-made structural features, including fire stations. The USGS will add leaf-off imagery to the US Topo products in New Jersey. This is a departure from use of the NAIP image and is being done at the request of the State of New Jersey. Additional US Topo products created in FY12 and beyond for the eastern United States may also include leaf-off instead of NAIP imagery. The addition of names for physiographic features and Public Land Survey System information will also be investigated. Finally, in the third year of the cycle, the USGS will begin to develop a plan for creating US Topo products for Alaska.

The National Atlas of the United States of America

The National Atlas of the United States of America® was originally published in 1970 and revitalized in 1997. The traditional bound collection of paper maps has been replaced by a new suite of online products and services. These include: more than a thousand authoritative and integrated small-scale geospatial datasets; multimedia stories about the use of these data; extensive documentation for each map layer; hundreds of page-sized printable maps; an interactive map maker; high quality wall maps; and innovative dynamic maps illustrating change. This online collection (*http://nationalatlas.gov*) is designed to offer reliable geographic information from many Federal agencies in forms that are useful to citizens and professional users alike. *The National Atlas* also produces the small-scale cartographic frameworks that the United States provides to the International Global Map of the Global Spatial Data Infrastructure and *North American Environmental Atlas* efforts. These fundamental map layers are being harmonized with data from mapping organizations in Canada and Mexico to produce a consistent digital base map of North America.

Historical Quadrangle Scanning Project

The U.S. Geological Survey (USGS) has produced topographic maps since 1879 at scales from 1:20,000 to 1:1,000,000. The earliest maps, intended to support minerals exploration, were published in quadrangle format at a scale of 1:250,000 for 1-degree maps and 1:125,000 for 30-minute maps. Gradually, the scale was increased to meet demands for more detailed mapping. The standard topographic map at 1:62,500 continued as the prevailing scale until the 1950's, when a continuing requirement for more detail resulted in a shift to a standard scale of 1:24,000. Approximately 250,000 editions have been published of all maps at all scales.

The USGS is cataloging and creating metadata to accompany high resolution georeferenced digital files of all lithographic maps. A complete copy of all metadata and digital files will be housed at the National Archives and Records Administration and the Library of Congress. Copies of appropriate segments of the collection may also be housed in map libraries, research institutions, and other government offices. All files will be in the public domain.

Scanning specifications and methods for accurate and efficient georeferencing of the scanned maps have been developed. The historical quadrangles will be released in conjunction with the new US Topo maps so that they will be available for reference and historical context. Currently (2010), more than 100,000 maps have been scanned, 55,000 have complete metadata and been converted to GeoTIFF files. Formats will be GeoTIFF for use in a GIS and GeoPDF for reference and plotting. All files will be available for viewing and downloading through the *The National Map* Web Site.

REFERENCES

Moore, Laurence R., et al. 2009. *US Topo Product Standard. About US Topo Maps*. 0.5.10, November 2009. Online: *http://nationalmap.gov/ustopo/about.html* (accessed 20 August 2010).

U.S. Department of Agriculture. 2010. *Imagery Programs. National Agricultural Imagery Program (NAIP)*. July 8, 2010. Online: *http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai* (accessed 10 August 2010).

U.S. Geological Survey. 2009. *Digital Map-Beta; 7.5-Minute Quadrangle Maps in GeoPDF. About US Topo Maps*. 0.0.25, July 2009. Online: *http://nationalmap.gov/ustopo/digital_map_beta_v0.0.25.pdf* (accessed 12 August 2010).

U.S. Geological Survey. 2006. *National Elevation Dataset*. August 2006. Online: *http://ned.usgs.gov/* (accessed 20 August 2010).

U.S. Geological Survey. 2010. National Hydrography Dataset. August 25, 2010. Online: http://nhd.usgs.gov (accessed 27 August 2010).

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Greg Allord is a senior cartographer with the USGS National Geospatial Program. He is the product lead creating a digital repository of all USGS topographic maps published since 1884.

Jay (John P.) Donnelly has served as the managing editor of the National Atlas of the United States since its revival by Congress in 1997. He directs all aspects of its product and service development.

Cartography at the University of Kansas

Margaret W. Pearce and Terry A. Slocum

The Department of Geography at the University of Kansas has maintained a commitment to cartography as an essential geographical tradition since a cartography program was founded by George Jenks in 1949. In that postwar era, when cartography as an academic discipline began to be defined and shaped, Jenks was among the foremost influences on American cartographic research and pedagogy. Although he remained the only cartographer on the faculty until the 1960s, intellectual interest in cartography was shared by other members of the department, a tradition of intersecting cartographic influence which continues today. Among the current 24-member faculty in KU Geography, George McCleary, Terry Slocum, Jerry Dobson, Stephen Egbert, and Margaret Pearce maintain a range of cartographic research interests, from geovisualization to design and aesthetics and map history. We integrate cartography with other geographical research areas, including GIS, hazards and risk, remote sensing, historical geography, spatial statistics, and Indigenous geography, according to our individual research interests.

Joining Jenks on the KU faculty in the 1970s, Associate Professor George McCleary trained as a cartographer under Arthur Robinson. When McCleary arrived at KU, he brought strong interests in map design and production. His emphasis on questions related to thematic map design, from the development of thematic technique, to the implementation of aesthetic design in print production, and the ways in which design theory and praxis can be taught, shape the KU undergraduate and graduate course curriculum. Most recently, McCleary presented his research in tourist map design at ICC 2009 in Santiago, Chile, and his research in cartographic design pedagogy at NACIS 2010 in St. Petersburg, Florida.

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Department Chair and Associate Professor Terry Slocum's research traditionally has focused on evaluating the effectiveness of new display approaches, including animation, visualizing uncertainty, and stereoscopic displays. More recently, he has explored the history of thematic maps, focusing on evaluating the design of thematic maps over the course of the twentieth century. He is the lead author of *Thematic Cartography and Geovisualization*, a widely used textbook in cartography classes, and in 2010 received an NSF Geoscience Education grant to examine the effectiveness of stereoscopic displays in introductory physical geography classes.

Professor Jerry Dobson has been working on a number of projects of interest to the cartographic community. Prior to his arrival in Kansas, Dobson studied cartography at the University of Tennessee; he later utilized this training for his contributions to the global population database *Landscan* during his tenure at Oak Ridge National Laboratory. *Landscan* continues to be a foundational thematic data source for cartographers worldwide. More recently, Dobson collaborated with colleague Peter Herlihy to develop participatory mapping techniques for the México Indígena project, and with colleague Stephen Egbert on a project to develop cartographic symbolization techniques for the portrayal of the landscapes of landmines. In 2008, Dobson received the Award of Distinction from the Cartography and Geographic Information Society (CaGIS), the first Distinguished Career Award for Lifetime Achievement to be conferred by the Society.

Associate Professor Stephen Egbert trained as a cartographer under Slocum and Jenks, with interests in the development of digital interactive techniques. During the last two years, Egbert has combined his subsequent, extensive research in remote sensing with his prior work in geovisualization. This synergy is reflected not only his collaboration with Dobson on landmine visualization and with Slocum on using 3D displays in the classroom, but as well in his work with Karen Roekard on the development of *geospatial genealogy*, which focuses on using digitized versions of historical cadastral maps together with data extracted from historical records to visualize and uncover patterns of residence, mobility, and tenure.

In 2010, Assistant Professor Margaret Pearce joined the KU cartography team, bringing interests in historical cartographic design, Indigenous cartographies, and geovisualization. Pearce's research continues to develop around the cartographic representation of place, historical experience, and Indigenous geographies. Recent projects in this area have included They Would Not Take Me There, a historical map produced in collaboration with the Canadian-American Center at the University of Maine, and the second edition of Exploring Human Geography with Maps, working with new co-author Owen Dwyer. Her current research focuses on the development of cartographic symbolization techniques for Wabanaki place names, and collaboration on an NSF-funded project mapping and representing climate change impacts on livelihood in the North Pare Mountains of Tanzania. Pearce served as the President of the North American Cartographic Information Society (NACIS) during 2009-2010, completing an eight-year tenure on the NACIS Board.

Also contributing to the cartography team is Special Collections Librarian Karen Cook of Spencer Research Library, moonlighting as a historian of cartography through her courtesy appointment in Geography. Cook completed her doctoral training in cartography and art history under Arthur Robinson at the University of Wisconsin, specializing in the history of print production in geological map design. Since her arrival at KU, Cook has combined her expertise in map history and library science by both contributing to the geography course curriculum, as well as connecting the department to the extensive historical cartographic holdings in Spencer Research Library Special Collections. Cook brought the History of Cartography Project to the halls of KU Geography, serving with Joel Morrison as an Associate Editor of Volume 6: *Cartography in the Twentieth Century during 2008-2011*, and contributing essays to volumes 4 and 6 in the series.

Additional KU resources nurturing cartographic research at KU include Cartographic and GIS Services (KUCS), where Darin Grauberger has been the Director since training under McCleary and then joining the Department in 1998. In keeping with the KUCS mission to provide quality cartographic renderings and GIS services at the university, regional, and national levels, the lab produces over 100 thematic, statistical and historical maps and illustrations annually, for printed material, wall maps, and the web. KUCS is currently engaged in a major project to produce the maps for James Shortridge's forthcoming book on the history of Kansas City.

Outside the department, we are supported by the over 440,000 maps and air photos of the Thomas R. Smith Map Collection housed in Anschutz Library and overseen by Map Librarian Scott McEathron; and the digitalization, spatial analysis, and large format print production support of the GIS and Data Lab under Rhonda Houser.

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GIScience at Penn State

Cynthia A. Brewer and Anthony C. Robinson

Research and teaching in Geographic Information Science at The Pennsylvania State University includes cartography, geovisual analytics, representation, ontologies and semantics, geographic information retrieval, qualitative and quantitative methods, spatial cognition, human factors, remote sensing, and GIS education. GIScience centers in the Department of Geography are GeoVISTA, which centrally organizes many GIScience research activities at Penn State, and the Gould Center, which focuses specifically on cartographic production and research. The department offers undergraduate and graduate degrees with specialization in GIScience, and its online geospatial education programs are supported by the John A. Dutton e-Education Institute at Penn State.

Resident GIScience Education

Students may specialize in GIScience within their master's and doctoral graduate studies in Geography as resident students at the University Park campus. The undergraduate GIScience option for the Bachelor of Science in Geography is complemented by an undergraduate minor in GIScience offered for students who major in other disciplines at Penn State. The cartography course sequence (detailed here given the context of reporting to the International Cartographic Association) begins with the overview of cartography, GIS, remote sensing, and spatial analysis offered by Mapping Our Changing World, with an associated online textbook Nature of Geographic Information: An Open Geospatial Textbook. Introductory cartography is one of four intermediate-level courses, and builds expertise in GIS-based reference and thematic map making. Advanced cartography-related courses include dynamic representation, applied cartographic design, geovisual technology use and usability, human computer interaction, and web mapping. Undergraduate students also work as teaching interns in the hands-on labs for GIScience courses and with researchers on projects in the centers. Example topics for recent graduate seminars in cartography include multiscale topographic mapping and generalization. Professors teaching GIScience at University Park are Cynthia Brewer, Andrew Carleton, Alexander Klippel, Alan MacEachren, and Donna Peuquet.

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Online GIScience Education

In collaboration with the John A. Dutton e-Education Institute and the Penn State World Campus, Penn State's Department of Geography has offered instructor-led online education for current and aspiring geographic information systems professionals since 1999. To date over three thousand students have enrolled in these programs from fifty U.S. states and all seven continents.

Three programs are currently offered. The Master of GIS degree program is designed for experienced practitioners who aspire to leadership in the geographic information systems profession, but who are only able to study part-time and at a distance. The Certificate Program in GIS helps practitioners to become knowledgeable and skillful users of geospatial data and technologies. The Graduate Certificate Program in Geospatial Intelligence helps analysts to combine spatial thinking, information literacy, and geospatial technology skills with knowledge of cultural and political geography and a commitment to ethical practice. Course content reflects the combined talents of twenty-nine GIScience faculty from the Department of Geography and the e-Education Institute. Courseware created for these online programs is freely available under a Creative Commons license as part of the Dutton Institute's Open Educational Resources initiative (http://open.ems.psu.edu). Key personnel include faculty members Anthony Robinson, Todd Bacastow, Beth King, Jim Detwiler, and program assistant Jan Moyer.

GeoVISTA Center

Established in 1998, the Penn State Geographic Visualization Science, Technology, and Applications Center is based in the Department of Geography but has faculty and graduate student affiliates in multiple colleges at the University Park campus. Its research is interdisciplinary and, over the past decade, its emphasis has expanded from geovisualization to cover all aspects of GIScience and related information sciences.

GeoVISTA faculty and students are charged with the mission to coordinate integrated and innovative research in GIScience, with an emphasis on geovisualization. New geographic data sources and corresponding demands for useful and usable technologies pose an array of research challenges and opportunities that the GeoVISTA Center is working to address. The focus is on developing powerful human-centered methods and technologies that allow scientists and decision makers to solve scientific, social, and environmental problems through computer-supported, visually-enabled analysis of the growing wealth of geospatial data. Examples of software designed to support these science goals include; ColorBrewer, GeoVISTA Studio, GeoViz Toolkit, Exploratory Spatio-Temporal Analysis Toolkit, Visual Inquiry Toolkit, Pennsylvania Cancer Atlas, and CrimeViz.

Research at the GeoVISTA Center has been supported by project funding from the National Science Foundation, National Institutes of Health, Department of Homeland Security, Department of Defense, and by several industry partners. As part of these research efforts, the GeoVISTA Center has built strong ties with the College of Information Sciences and Technology and with faculty at the Hershey Medical School. In addition, GeoVISTA has recently initiated a cross-campus pilot project with the Center for Infectious Disease Dynamics on Geovisual Analytics for Infectious Disease Dynamics.

In 2008, the GeoVISTA Human Factors in GIScience lab was founded by Alexander Klippel to advance the understanding of how humans cognize geographic space. Research in the Human Factors lab addresses how humans communicate spatial information in different modalities (e.g., linguistically and graphically), how cognitive processes can be formally characterized, and how to advance empirical methods to learn about spatial cognition. As such, the Human Factors Lab is an interdisciplinary group collaborating with researchers in geography, linguistics, information science and technology, informatics, and psychology.

GeoVISTA faculty in Geography include Alan MacEachren (Director), Donna Peuquet (Associate Director), Justine Blanford, Cynthia Brewer, Gouray Cai, Jin Chen, Frank Hardisty, Deryck Holdsworth, Krzysztof Janowicz, Alexander Klippel, Scott Pezanowski, and Anthony Robinson. There are also nine additional faculty associates in other departments at Penn State.

The Gould Center

The Peter R. Gould Center for Geography Education and Outreach supports the university's missions of instruction, research, and service through excellence in cartography. Primary projects are the National Mapping Expertise Exchange and Penn State campus maps. The Gould Center also designs and produces custom maps and information graphics for clients. Geography department members involved in the center are Professor and Director Cynthia Brewer, Writer-Editor Michael Dawson, and Cartographer Michael Hermann. The Gould Center is guided by three goals: advancing national mapping innovation, providing cartographic services to the university and scholarly communities, and expanding student experience through internships.

Many federal mapping projects seek advice and collaboration on best practices for map labeling, generalization, multi-scale mapping, symbol design, color use, cartographic data modeling, terrain representation, data classification, page layout, cross-agency data use, and other cartographic challenges. The National Mapping Expertise Exchange promotes innovation and excellence in national mapping by building connections among mapmakers, educators, researchers, and software developers at academic, commercial, and governmental organizations.

Links for Penn State GIScience are collected at *http://www.geog.psu.edu/research/giscience*.

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Geospatial Research, Education and Outreach Efforts at the University of Minnesota

Susanna McMaster, Rob Edsall and Steven Manson

The University of Minnesota has had a strong history and tradition in the field of geospatial (or geographic information) science and cartography. The University is one of seven founding members of the University Consortium for Geographic Information Science and home to key departments, to geospatial research and education centers and programs, as well as to myriad resources found in libraries and laboratory facilities on campus.

As an early pioneer institution in GIS, the University of Minnesota has a longstanding interest in research and education in geospatial science. The University of Minnesota helped create, in the 1960s, one of the first Geographic Information Systems, the Minnesota Land Management Information System, and in the 1990s, a leading open source web-mapping application, MapServer. Such collaboration has made the State of Minnesota very recognized for its progressive implementation of GIS in local, county and state government, in programs and agencies such as MetroGIS, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, and Minnesota Department of Transportation. Presently, over ninety faculty at the U of M engage in geospatial science or cognate fields via research, teaching, or outreach.

We offer over seventy courses in GIS or related topics that contribute to two undergraduate, three masters, and three doctoral programs including the professional Masters in GIS (MGIS) degree program, the first of its kind in the United States. Both the undergraduate interdisciplinary minor and MGIS program have a multidisciplinary focus that involves the collaboration of various departments and colleges across the campus. The undergraduate interdisciplinary minor was developed based on collaboration amongst four colleges on campus including the College of Liberal Arts, College of Food, Agricultural and Natural Resources Science, College of Science and Engineering, and College of Design. We also conduct research on U.S. academic cartography and professional GIS education as well as general aspects of GIS education. For example, GeoWall, a tool for 3-D visualization, is being used to incorporate technology-enhanced learning into the geography curriculum.

The University has many internationally known GIS research centers, including the Center of Urban and Regional Affairs (CURA), the National Historical GIS, the Spatial Databases and Data Mining Research Group, and Environmental Resources Spatial Analysis Center (ERSAC). CURA also supports important GIS and cartography-related outreach with the local community through the University Neighborhood Network, a system designed to match up University resources with local community development projects. The Minnesota Population Center's National Historical GIS supports social science research and also provides GIS and cartographic training and services. The Spatial Databases and Data Mining Research Group, associated with the Computer Science department, focuses its research on the storage, management and analysis of scientific and geographic data, information and knowledge including application areas in transportation, virtual

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environments, Earth science, epidemiology, and cartography. ERSAC features about 20 faculty and 50 graduate students from eight departments and five colleges with common research interests in the geospatial analysis of natural resources and the environment.

The University's Geospatial Science page provides additional details about GIS and cartography related activities on the University of Minnesota campus: http://geospatial.umn.edu/index.htm .

Other key resources can be found within the University's library system and laboratory facilities. The University Library system includes geospatial resources (both current and historical) at the John Borchert Map Library (including the publically-accessible Automated Cartographic Information Center), the James Ford Bell Library with its recent acquisition of the Ricci Map, and the Forest Resources library that houses an extensive collection of remote sensing related materials. Key geospatial labs on campus include the Digital Cartography Lab, the Advanced Geographic Information Science Lab, the Geographic Analysis and Mapping Lab, the Remote Sensing and Geospatial Analysis Laboratory, and the Soil and Landscape Analysis Lab. The Duluth campus is home to the Natural Resources and Geographic Information Systems (NRGIS) Laboratory.

The Department of Geography has long had a strong focus on geographic information science (GIScience) including the early pioneering work by John Borchert, member of the National Academy of Science. Our faculty conduct research in spatial analysis and modeling of social and natural processes, visualization and data mining of complex information, and examination of the relationships between society and spatial technologies.

Many faculty contribute to advances in GIScience at the University of Minnesota. Rob Edsall, Francis Harvey, Mark Lindberg, Steve Manson, Robert McMaster and Susanna McMaster conduct research in many areas in GIScience, including institutions, analysis, modeling, cartography and scale, ethics and GIS education. Kurt Kipfmueller, Kathy Klink, and Scott St. George all conduct research using GIS, and increasingly, about GIScience topics including dynamic spatial modeling and spatiotemporal analysis. Helga Leitner, Eric Sheppard, and Roderick Squires contribute to GIScience via land mapping and surveying, social and environmental justice, GIS and society, and integrating GIScience methods with other approaches. Recent GIS curricular efforts include making the introductory GIS course a writing- and active-learning-focused course and adding courses that respond to the current advancements in geospatial technology such as the Digital Planet and Mapping Our World courses for undergraduates.

Campus-wide geospatially-oriented community outreach efforts include community-based GIS and cartography projects led by researchers and staff at the Center for Urban and Regional Affairs, the EcoEducation K-12 education initiative led by Steve Manson, and Cyclopath, a geowiki designed to serve the Twin Cities biking community, led by the human-computer interaction and social computing research group in the Department of Computer Science and Engineering. University faculty members serve on various geospatial advisory boards such as the Statewide Geospatial Advisory Council and National States Geographic Information Council. Additionally, many faculty, staff and students are involved with the key regional non-profit GIS organization known as the Minnesota GIS/LIS Consortium. The GIS Student Organization is an official campus-wide student organization founded by students in the MGIS program and includes both undergraduate and graduate student members from across the campus. They organize key public events such as the GIS Job and Career Networking Fair each spring term and a GIS Day Event that coincides with the John Borchert Lecture in the fall.

The University of Minnesota continues its tradition as a leader in geospatial research, education, and outreach. At the U of M, we recognize and actively promote the interdisciplinary connections that GIScience makes possible, positioning our discipline as a flagship in modern, problem-oriented, and society-relevant academia.

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Rob Edsall has been an assistant professor of GIS and cartography at the University of Minnesota since 2008, and will begin an appointment as an associate professor at Carthage College in Kenosha, Wisconsin in Fall 2011. He teaches cartography, GIS, and research methods, and is involved in research in geovisual analytics, multimodal interface design, and GIScience-society interaction.

Steven Manson is an associate professor in the Department of Geography at the University of Minnesota in the Twin Cities where he also directs the Human-Environment Geographic Information Science lab. Dr. Manson combines environmental research, social science approaches, and geographic information science to understand complex human-environment systems

Cartographic Research at the University South Carolina

Sarah Battersby

The GIScience program at the University of South Carolina is broad and interdisciplinary in focus. The geography department is considered to be one of the leading American contributors in cognitive cartographic research in the late twentieth century, and much of our current work carries on this tradition of research to improve communication of complex spatial information. With specific respect to our cartography and geovisualization program, faculty and graduate students are currently engaged in research on in a variety of areas, such as cognitive and perceptual issues in dynamic or interactive map communication, user interface design, cartographic communication of risk and uncertainty information, and cognition of remotely sensed imagery.

The faculty and students in the department are also engaged in active research on the development of new theory, methodology, and their applications to help understand massive and complex spatial data, acquire new insights and knowledge, and better support decision and policy making. Specifically, this work includes research on the development of new computational, visual-analytic, and statistical methods to process, analyze, and understand complex information in massive geospatial and temporal data. This work addresses critical application problems concerning the environment and society, and the interactions among them, such as climate change, public health, security, migration, and transportation.

The geography department at the University of South Carolina has five faculty members in GIScience, including Sarah Battersby, Diansheng Guo, Michael Hodgson, John Jensen and Christopher Upchurch. The Department also houses two full-time staff members to support GIScience activities in the department, and on campus. The faculty and staff members in the department collectively offer a substantial set of graduate and undergraduate courses in geographic information systems and science, cartography, visualization, GNSS, and remote sensing. In the fall of 2010, the Department had eighteen graduate students pursuing GIScience-based degrees (6 Masters; 12 PhD). The University of South Carolina houses the GISciences Research Lab, which provides technical staff and facilities to support a full range of cartography, GIS, and remote sensing applications.

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Cartography at The Ohio State University

Ola Ahlqvist

History and Present Strengths in Teaching and Research

The history and traditions of cartography at OSU have been thoroughly described by a previous report in this journal (Moellering 1991). OSU continues to be at the forefront of comprehensive research and education in Cartography and in the wider realm of Geographic Information Science.

Cartography education at OSU is offered by three units. The Civil and Environmental Engineering and Geodetic Science Department offers an undergraduate minor in surveying and mapping. This minor qualifies students for the 'Fundamentals of Surveying Exam,' along with a BS degree in Civil Engineering, as a first step toward licensure as a professional surveyor. A MS and PhD in civil engineering with a geodetic engineering specialization is also offered. The School of Earth Sciences offers a graduate degree in Geodetic Science with specializations in geodesy, and mathematical geodesy.

The third unit offering cartography education is, of course, OSU's Department of Geography, continuously recognized among the elite geography departments in the United States, and recognized globally as a leader in cartographic, spatial analytic and GIS-related teaching and research. During the early 2000's the department faced the challenge of replacing two eminent, senior faculty members in the area of cartographic, visualization, and GIScience research and education. Prof. Harold Moellering (now emeritus) has made significant contributions to two- and three-dimensional cartographic visualization strategies, and his leadership role in the U.S. National Committee for Digital Cartographic Data Standards was instrumental in providing a foundation for geographic data infrastructure developments that continue to this day. Professor Duane Marble (now emeritus) is recognized as a distinguished scholar in the fields of transportation geography, computer modeling and simulation, and for pioneering research in geographic information science. He also chaired the national Model Curricula Task Force where he led the work to develop the Geographic Information Science and Technology Body of Knowledge 2006 (DiBiase et al. 2006), which has been highly influential in the development and modernization of academic GIS programs and as a benchmark for a professional GIS certification.

With new faculty appointments filling positions of these and other recently retired professors, OSU's Geography Department has been reinvented over the past decade. Fifteen of the twenty-six faculty members have been hired since 2000. We now have a department that builds on existing strengths while forging new directions in emerging areas of the discipline. In GIScience alone, innovative research at OSU includes activity in social computing, web cartography, critical cartography, and semantic visualization.

Concurrently, of course, the field of cartography has also been reshaped, from a relatively narrowly defined field of mapmaking to a conglomerate of technology, infrastructure, theory, and practice, informed by a massively increasing number of practitioners. Consequently, cartographic research and education at Ohio State should not only be characterized in terms of those faculty members with a direct technical and/or methodological focus. Many faculty with core interests in the social and earth sciences make significant contributions to critical- and

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application-oriented perspectives on cartography. In their work, ranging from the investigation of Peruvian water resource problems to the study of border and immigration control to the addressing of the impact of climate change in Greenland, researchers at OSU often push the limits of cartography, employing cutting-edge cartographic methods as well as a critical re-examination of the roles of maps and mapping in addressing some of the Earth's most challenging problems.

Developing a New Major in Geographic Information Science

While our faculty push GIScience research forward, we have also recognized the need to re-think our education of a subject in constant flux. A natural part of the rejuvenation process in the Department of Geography was therefore to revisit the curriculum in GIS and Cartography. As a result the Geography department is now about to launch an exciting new major in Geographic Information Science based on the UCGIS Body of Knowledge model.

This new major is the result of an extensive and collaborative review of course content by faculty and students specializing in cartography and GIS, against the external standards of excellence suggested in the BoK report. The assessment helped identify overlaps and gaps in our curriculum with respect to the core competencies recommended in the BoK. While subjects of cartography and geovisualization were still well covered by courses and new faculty interests, our curriculum review indicated a lack of sufficient coverage of some fundamental knowledge areas related to ethics and remote sensing, and redundant coverage of some conceptual foundations. The new major (pending approval by the Ohio Board of Regents) will take students through a comprehensive GIScience curriculum. It is divided into three parts; a) required prerequisites in computer programming and statistics, b) core requirements in quantitative geographic methods, geovisualization, and GIS, and c) electives such as seminars, added depth in core areas, and added breadth in related topics, for example Land Use and Transportation Geography. Cartography and visualization is one of the central knowledge areas in this major, and it will prepare students for future careers in an increasingly spatially aware world.

REFERENCES

DiBiase, D., M. DeMers, A. Johnson, K. Kemp, A. Taylor Luck, B. Plewe and E. Wentz. 2006. *Geographic Information Science and Technology Body of Knowledge*. Association of American Geographers: Washington, DC.

Moellering, H. 1991. Cartography at Ohio State University. *Cartography and Geographic Information Science* 18(3), 201-204.

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The History of Cartography Project

Beth Freundlich

The History of Cartography Project is moving ever closer to meeting the ambitious goal set by founders J. B. Harley and David Woodward in 1977. They envisioned a unique multi-volume reference work that would examine maps as tools and as records of societal worldviews and perceptions of space from prehistory through the twentieth century. The project has developed into a comprehensive six-volume reference work of international repute. Three volumes have been published to date: Volume 1, *Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean* (1987), ed. J. B. Harley and David Woodward; Volume 2.1, *Cartography in the Traditional Islamic and South Asian Societies* (1992), ed. J. B. Harley and David Woodward; Volume 2.2, *Cartography in the Traditional East and Southeast Asian Societies* (1995), ed. J. B. Harley and David Woodward; Volume 2.3, *Cartography in the Traditional African, American, Arctic, Australian, and Pacific Societies* (1998), ed. David Woodward and G. Malcolm Lewis; and Volume 3, *Cartography in the European Renaissance*, ed. David Woodward (2007).

Over the past several years, *The History of Cartography* series has seen many noteworthy developments. A significant change is in the structure of the presentation of information in the final three volumes of the series. Volumes Four, Five, and Six, which cover the Enlightenment, the Nineteenth, and the Twentieth Century, respectively, are structured as interpretive encyclopedias. The encyclopedic format offers a number of advantages over the lengthy narrative chapters written by a relatively small number of experts for Volumes One, Two, and Three. By integrating contributions from a large number of wide-ranging scholars—approximately 275 for each of the last three volumes—the new format makes the project a more broadly cross-disciplinary effort and helps the editors evaluate relative topical coverage. Readers can access information through the alphabetically organized entry terms, by consulting the comprehensive index, and by using the cross-referencing provided both within and between entries. The carefully selected reference list at the end of each entry will provide valuable signposts for scholars who consult the *History* as a reference tool. Obscure but important technical and biographical facts will be made more accessible in self-contained entries rather than being embedded in longer essays. The encyclopedic format also allows the editors to keep tight control on the size of the volume. The relatively brief format of individual encyclopedic entries will balance breadth with depth of coverage.

The final three volumes are being prepared concurrently under the editorial direction of Matthew Edney and Mary Pedley (Volume Four), Roger Kain (Volume Five), and Mark Monmonier (Volume Six). Stages of preparation include volume design; commissioning authors and monitoring their progress; receipt, translation, and editing of manuscripts; fact and reference checking, illustration acquisition, and quality control; assembly of the final volume; and print and digital publication. In order to move manuscripts more quickly from author submission to fact and reference checking, Edney, Pedley, and Monmonier have recruited editorial assistants Dennis Reinhartz and Sarah Tyacke for Volume Four and Peter Collier, Karen Cook, Jon Kimerling, and Joel Morrison for Volume

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Six. Kain has enlisted help from Imre Demhardt and Carla Lois for Volume Five.

Between 2006 and 2011, Volumes Four and Six moved from recruitment of the first contributors to editing, fact checking, and procurement of illustrations. Indeed, by the end of March 2011, authors had submitted 90% of the entries for Volume Six. Monmonier aims for publication in 2014. By the same date, contributors had submitted about 66% of the Volume Four entries. Kain was appointed editor of Volume Five in 2008, and he set the nineteenth century volume in motion with a draft list of entry terms and establishment of an advisory board. Public meetings were held in conjunction with the Commission on the History of Cartography of the International Cartographic Association (ICA) during their 2009 and 2010 conferences to discuss concepts and challenges for Volume Five and to explore subjects that are essential to understanding nineteenth-century cartography. The structure and content of Volume Five is now well developed, but contributors will not be formally contracted to write until the series publisher, the University of Chicago Press, approves a prospectus (targeted for 2013).

The History of Cartography Project has had great success establishing an international team of authors from many different disciplines, historical periods, and personal interests. Volume Four has contributors from 27 countries actively writing for the volume (70% of these are based outside the US or UK); Volume Six contributors are from 29 countries (with 38% outside the US or UK). In addition to those who come to the project with expertise in geography and history, many authors have backgrounds in fields as broad ranging as anthropology, architecture, astronomy, classics, economics, law, physics, or religion. The David Woodward Memorial Fellowship, made possible by a private donor, has provided two-month residencies at the Institute for Research in the Humanities at the University of Wisconsin–Madison for ten scholars from nine countries in the decade since it was founded. Their time is devoted to researching and writing on a topic related to a forthcoming book in the series.

A variety of venues have served to introduce authors to one another, to the editorial team, and to the aims of the project. In March 2008, editor Mary Pedley hosted a *réunion de travail* at the Bibliothèque Nationale de France as a way to coordinate the many France-based contributors to Volume Four. The two most recent International Conferences on the History of Cartography (2009, Copenhagen, and 2011, Moscow) included sessions for authors and friends of the series at which the editors made brief presentations, answered questions, and encouraged dialog.

The University of Chicago Press is committed to printing all illustrations in color for forthcoming volumes in the series and is pursuing options for digital publication. Color began to bear significant meaning in many forms of mapping during the eighteenth century and proved to be a key aspect in how nineteenth- and twentieth-century maps communicated information. Editors no longer have to painstakingly choose a very limited number of images to reproduce in color and isolate them from the text in separate color galleries. Instead, all illustrations will be printed in full color and positioned near the entries in which they are discussed. This will add to the usefulness of Volumes Four, Five, and Six and help make the books reference tools of first resort. Furthermore, the digital publication of forthcoming volumes and republication of existing volumes will ensure that the *History's* provision of intellectual access to early maps reaches the widest possible audience. Details of digital publication, including the cost, copyright, and website design are in an early stage of development as the University of Chicago Press prepares a viable business plan for this endeavor. Although many variables exist, the History of Cartography Project and the University of Chicago Press agree that the truly invaluable resources of the text, captions, precise references to images, and bibliographic apparatus of the volumes will remain intact.

The History of Cartography is made possible by essential and long-term support provided by the National Endowment for the Humanities and the National Science Foundation, as well as other generous and consistent sponsors including the University of Wisconsin–Madison College of Letters and Science and Graduate School (Wisconsin Alumni Research Foundation), the

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Cartography and Geographic Information Society (CaGIS)

Alan M. Mikuni

The Cartography and Geographic Information Society (CaGIS) consists of over 500 cartographers and GIScience professionals. The mission of CaGIS is to support research, education, and practice in cartography and GIScience in order to improve the understanding, creation, analysis, and use of maps and geographic information, thus enabling effective decision-making and ultimately improving the quality of life. CaGIS provides for the exchange of original concepts, techniques, approaches, and experiences by those who design, implement, and use cartography, geographic information systems, and related geospatial technologies.

As an influential worldwide network of developers, researchers, and educators in the field of cartography and GIScience, CaGIS continues to be active in many activities and endeavors that promote our discipline. We promote communication among our international community through the Society's journal *Cartography and Geographic Information Science* and a major biennial conference, AutoCarto. We represent the United States as a member organization of the International Cartographic Association (ICA), and sponsor an annual map competition that recognizes excellence in map design with recognition awards from National Geographic and Rand McNally. We also support graduate research in GIScience with $1500 of competitive scholarship awards to students around the world. Additionally our goals include the facilitation of the transfer of cartographic and GIScience knowledge among and within academia, government, and private industry, and the promotion of best professional practices, standards, and tools to create, use, and visualize geographic information.

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CaGIS has a proud heritage of service to its membership in the United States and internationally. The Society has long been involved in activities that support the cartography and geographic information science community, first as the Cartography Division of the American Congress on Surveying and Mapping (ACSM), then as the American Cartographic Association of ACSM, and currently, as CaGIS.

In 2008, the CaGIS Board of Directors conducted extensive analyses related to its organizational placement within ACSM. The Board concluded that it would be in the best interests of the future of CaGIS' leadership in the cartography and GIScience profession to become independent of ACSM. Extensive communications with the CaGIS general membership, including a vote resulting in majority support for independence, were conducted. In January 2009, the CaGIS Board notified the ACSM Executive Director and the ACSM Member Organizations of CaGIS' intention to become independent of ACSM. The ACSM Bylaws stipulate that "An Organization can withdraw from ACSM upon a two year advance notice to the Organization. All dues and fees must remain current for the two year period prior to withdrawal." Given the foregoing, CaGIS' withdrawal from ACSM would become effective in January, 2011. During the intervening 2 years, the CaGIS Board conducted reviews of organizational structure and operations to ensure that it could be successful as an independent organization. One aspect of an independent CaGIS would be the flexibility to engage in relationships with other kindred organizations, both domestic and international. Outreach to other organizations was part of the 2009-2011 transition strategy. In November 2010, CaGIS partnered with the American Society for Photogrammetry and Remote Sensing (ASPRS) in conducting a successful Fall ASPRS/AutoCarto 2010 conference in Orlando Florida. CaGIS is also assuming leadership for a bid to the International Cartographic Organization community o host the 2015 International Cartography Conference in the United States. In addition, CaGIS continues to receive requests for partnering on other conferences and events.

CaGIS provides online access to its journal *Cartography and Geographic Information Science* and to proceedings of AutoCarto on its newly redesigned and implemented website, ***http://www.cartogis.org***. CaGIS' Journal is ranked eighth among 46 journals, internationally, that publish the findings of GIScience research. The other official journals of the ICA, *Cartographica* (Canada) and the *Cartographic Journal* (UK), are also included among this elite group.

Through its membership in the Coalition of Geospatial Organizations, (COGO), an eleven member organization consisting of kindred associations in the geospatial community, CaGIS has increased its participation in the geospatial policy arena. Among the issues about which COGO has deliberated and has put forth unified statements in support of various Federal geospatial programs, are: funding for geospatial programs under the American Reinvestment and Recovery Act (ARRA), urging Congressional support for geospatial education, the USGS National Map, and establishment of a subcommittee on geospatial activities within the Congress. Other issues deliberated by COGO, but which did not receive unanimous consent among members included the "MAPPS lawsuit." MAPPS and other organizations sued the United States to revise the Federal Acquisition Regulation provisions associated with the Brooks Act (Architect and Engineering, Qualifications-Based Selection), and to revise the definitions of surveying and mapping within the Act. The case was dismissed in 2007 on procedural grounds.

CaGIS became an independent organization in January 2011, and the CaGIS Board is actively pursuing initiatives to move the organization forward as the leader in the international cartography and GIScience community. CaGIS has a newly designed, user-friendly website, ***www.cartogis.org*** that provides information about the organization, its many activities and publications.

About the Author: *Alan M. Mikuni* is past president of CaGIS, and recently retired from the United States Geologic Survey after serving 44 years as Western Regional Geographer and the Chief of the Western Mapping Center. Alan is currently employed by Towill, Inc. in San Francisco, California.

The North American Cartographic Information Society (NACIS)

Margaret W. Pearce

The last two years have been exciting and productive for the North American Cartographic Society (NACIS). We continue our dedication to the fostering of communication among the disparate producers, users, and archivers of cartographic information in North America, while also educating the public and influencing government policy on cartographic matters. The NACIS annual conference is the centerpiece of our year, and we have enjoyed strong attendances and participation on both coasts, meeting in Sacramento, California, in 2009 and in St Petersburg, Florida, in 2010. In the spirit of our diverse cartographic community, we continue to develop activities for our conference that emphasize themes of inclusiveness and mentoring across the cartography spectrum, enlivening the conference experience and nurturing the networks and collaborations that result. We have also continued our tradition of an annual pre-conference, at which Practical Cartography Day continues to offer cartographers the opportunity to share and teach project organization and technique. In 2009, the pre-conference tradition was expanded to make room for a second, parallel event, Practical Map Librarian's Day, where map librarians also have the opportunity to share and teach practical skills of the cartographic archive. The success of PMLD in Sacramento has now established it as a new conference tradition. And in keeping with our goal to support student participation and recognition, we have expanded our popular Student Web Map and Student Poster competitions with a new competition for Student Paper Presentations, to be launched in 2011.

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Aside from these conferences, we have also been expanding the scope of our Society in new creative directions. One of these major accomplishments has been the shepherding of our journal, Cartographic Perspectives, to an open access digital format, accessible on our website, www.nacis.org. Open access comprises both a new format and a new attitude toward the sharing and disseminating of cartographic research and production. For example, CP is now uniquely positioned to support peer-reviewed publication for interactive and animated cartographies and associated research. Open Access also accelerates the time between manuscript submission and publication, while providing wider dissemination of published work. At a time when cartographic creativity continues to be explored and expressed in digital forms, and when library journal budgets are reduced on an annual basis, an online Open Access journal was the logical step for the maintenance of CP as a viable and valuable journal. NACIS has also recently taken over the management of CartoTalk, the Public Forum for Cartography and Design, (cartotalk.com). NACIS responsibilities include managing all aspects of the public face of the forum, from membership to general discussion contributions and input, to the behind-the-scenes work of advertising, programming, and forum software. With our new responsibility, we are also exploring the publication of an annual cartographic design publication to showcase new talent and innovations in the field.

Under the leadership of NACIS president

Tanya Buckingham, we look forward to more innovative changes to the Society in 2011, as our website is redeveloped to host our ever-expanding digital presence, and we continue to dedicate awards and travel scholarships to foster engagement among all of our members. Plans for NACIS 2011 are underway, when we will return to one of our most popular venues, Madison, Wisconsin.

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