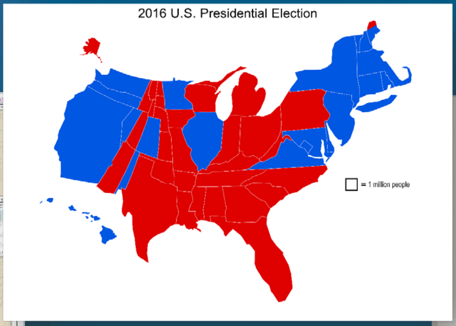
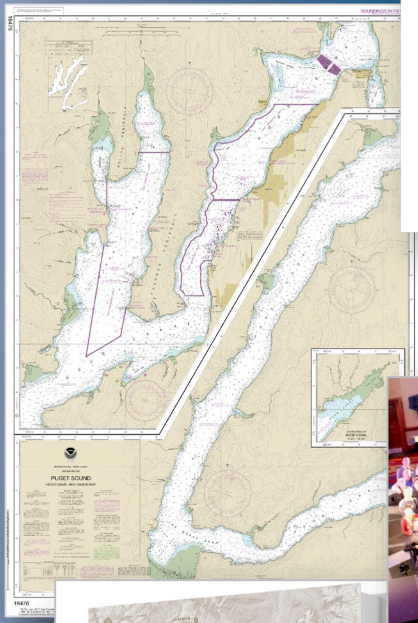
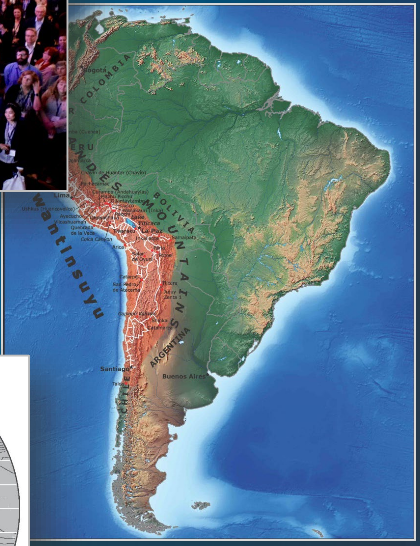
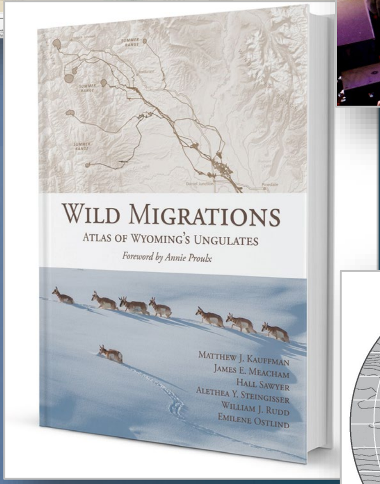
2019 US National Report

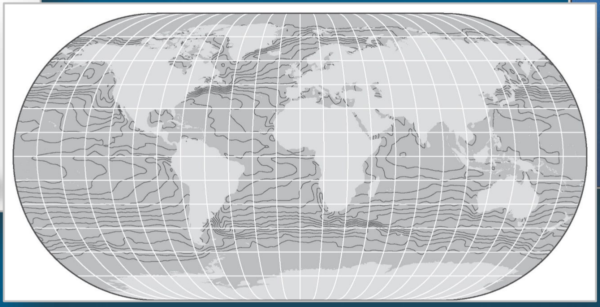
ICC 2019 | July 15-20 | Tokyo, Japan











Organized by the US National Committee for the ICA—a committee of the Cartography and Geographic Information Society

Table of Contents

Suggested citation (example using Zou et al.)

Zou, Lei, Nina S. N. Lam, and Heng Cai. 2019. "A Framework for Analyzing and Visualizing Twitter Use Patterns during Natural Hazards." US National Report (US National Committee for the International Cartographic Association) (July 2019), accessed July 8, 2019, https://cartogis.org/usnc-ica/us-national-report/.

US Cartographic and Other Organizations

Institutions and Agencies

Cartography Labs

Research

2019 US National Report: Introduction

Aileen R. Buckley

Esri, 380 New York Street, Redlands, CA 92373, abuckley@esri.com

Every four years, the US National Committee (USNC) for the International Cartographic Association (ICA) publishes the US National Report. The report summarizes cartographic and geographic information science (GIScience) activities in the nation during the previous four years across all sectors, including academia, industry, and government. The report is provided to all members of the ICA and, by extension, its member nations. The USNC also shares this with the US cartographic and GIScience communities.

The 2019 US National Report has two parts: a single peer-reviewed *Cartography and Geographic Information Science* (*CaGIS*) article that explores the recent state of and future prospects for cartographic research in the US, and an online report that provides detailed information from contributors across all sectors.

The open-access article appears in volume 46, issue 3, June 2019, of the *CaGIS* journal along with a one-page editorial explaining that the article is part of the 2019 US National Report (Buckley 2019). The article, by Keith C. Clarke, J. Michael Johnson, and Tim Trainor, is titled "Contemporary Cartographic Research: A Review and Prospective" (Clarke et al. 2019). The authors reflect on the accomplishments and shortfalls of the past and contemplate the possibilities and challenges for the future. The article addresses five overarching thematic topics (information visualization, cartographic data, spatial analysis and applications, methods and models, and GIScience) that were determined analytically through a content analysis of the titles of peer-reviewed research articles in five cartographic and GIScience journals over the past four years.

While this review of recent cartographic research paints an important part of the nation's cartographic and geographic information science picture, the online report completes the story with details about the achievements and activities of organizations and institutions; methods for the development, management, and dissemination of cartographic data and products; the design and development of software, web, mobile, and other apps; applications of cartographic and geographic information system (GIS) techniques within domain areas; novel cartographic methods and technologies; emerging technologies in mapping; and unique interdisciplinary activities in cartography and GIScience.

This format for the 2019 US National Report is a departure from the norm. In the past, the US National Report has consisted of a full issue of *CaGIS* and its predecessors (Bevington-Attardi and Rice 2015, Edsall 2011, Leitner and Skupin 2007, Harvey 2003, Brewer 1999, Slocum 1995, McMaster 1991, Loy 1987, and Preface and acknowledgements 1984). Although different from the format of previous national reports, the combination of the *CaGIS* article and the online report provides a very comprehensive and detailed review of the cartographic and GIScience activities in the US over the past four years.

References

Bevington-Attardi, D. and M. Rice. 2015. "On the Map: American Cartography in 2015." *Cartography and Geographic Information Science* 42, sup1, 1–5. doi: 10.1080/15230406.2015.1060112.

Brewer, C. A. 1999. "The State of US Cartography," *Cartography and Geographic Information Science* 26:3, 165–166. doi: 10.1559/152304099782330662.

Buckley, A. R. 2019. Editorial: "2019 US National Report to the ICA." *Cartography and Geographic Information Science* 46:3, 195. doi: 10.1080/15230406.2019.1574554.

Edsall, R. 2011. "American Cartography 2011: Benchmarks and Projections," *Cartography and Geographic Information Science* 38:3, 246–249. doi: 10.1559/15230406382246.

Harvey, F. J. 2003. "Transitions in US Cartography and Geographic Information Science." *Cartography and Geographic Information Science* 30:2, 95–98. doi: 10.1559/152304003100010983.

Leitner, M., and A. Skupin. 2007. "Cartography 2007: Reflection, Status, and Prediction." *Cartography and Geographic Information Science* 34:2, 73–75. doi: 10.1559/152304007781002217.

Loy, W. G. 1987. Preface and acknowledgments to *The American Cartographer* 14:3, 196. doi: 10.1559/152304087783875831.

McMaster, R. B. 1991. Introduction to *Cartography and Geographic Information Systems* 18:3, 149–150. doi: 10.1559/152304091783786916.

Slocum, T. A. 1995. Introduction to *Cartography and Geographic Information Systems* 22:2, 109–114. doi: 10.1559/152304095782540474.

1984. Preface and acknowledgments/author addresses to *The American Cartographer* 11:sup1, 4. doi: 10.1559/152304084783943847.

US National Committee for the ICA

Aileen R. Buckley

Esri, 380 New York Street, Redlands, CA 92373, abuckley@esri.com

Keywords: USNC, CaGIS, International Cartographic Association (ICA), International Cartographic Conference (ICC), International Cartographic Exhibition (ICE), Barbara Petchenik Children's World Map Drawing Competition

Abstract

The US National Committee (USNC) for the International Cartographic Association (ICA) is a standing committee of the Cartography and Geographic Information Society (CaGIS). Its primary responsibility is to act as the liaison between ICA and CaGIS, as well as the larger US cartographic community. The USNC performs a number of important functions, most of which are related to US participation in the ICA and the ICA's International Cartographic Conference (ICC), which is held every other year. This paper details the accomplishments in these USNC functions in the four years since the ICC 2015 in Rio de Janeiro, Brazil, in August 2015.

Introduction

The USNC is a standing committee of CaGIS, the US adhering body to the ICA. The primary responsibility of the USNC is to act as the liaison between ICA and CaGIS, as well as the larger US cartographic community.

The USNC performs a number of important functions, most of which are related to US participation in the ICA and the ICA's ICC. These functions include the following:

- Submission of nominations for US candidates of ICA awards
- Submission of nominations for US candidates for the ICA Executive Committee
- Submission of proposals for ICA commissions with US chairs
- Submission of US entries in the International Cartographic Exhibition
- Submission of US entries in the Barbara Petchenik Children's World Map Drawing Competition
- Provision of USNC travel funding to help American and international scholars at US institutions attend the ICC
- Submission of the US National Report

Nominations for US Candidates for ICA Awards

For the ICC, ICA member nations may submit nominations for candidates from their nations for ICA awards. At ICC 2017, Timothy Trainor was awarded the ICA Honorary Fellowship, which is presented to cartographers of international reputation who have made special contributions to the ICA. Diplomas for Outstanding Services to ICA were awarded to Aileen R. Buckley, Cynthia A. Brewer, and Matthew Rice for their efforts in helping to organize the ICC 2017, which was held in the United States. The USNC also supported eight applications for the ICA scholarship to attend the ICC. The goal of these grants is to stimulate young scientists or professionals to direct their careers toward fundamental studies in the fields of cartography and GIScience. There are two types of scholarships—one to attend the ICC and one to attend an ICA workshop. Of the eight US applicants, four were awarded ICA scholarships.

For the ICC 2019, the USNC submitted a nomination for Dr. Harold Moellering to receive the Diploma of Outstanding Service to the ICA. The USNC also supported 13 applications for the ICA scholarship and 2 to attend ICA workshops. Of the 15 US applicants, 6 were awarded ICA scholarships.

Nominations of US Candidates for the ICA Executive Committee

For the ICA General Assembly, which is held every four years, ICA member nations may submit nominations for candidates from their nation for positions on the ICA Executive Committee. For the 18th General Assembly at ICC 2019, the USNC nominated Trainor as a candidate for president of the ICA for the 2019–2023 term. The USNC also nominated Moellering to serve as honorary auditor for the 2019–2023 term. Moellering served in this capacity for the 2015–2019 term.

Proposals for ICA Commissions with US Chairs

For the ICA General Assembly, ICA member nations may submit nominations for ICA commissions with chairs from their respective countries. ICA commissions perform most of the substantive and apparent work of the ICA. The ongoing interests and strengths of the ICA are reflected in the operational fields of its current commissions. Continuing and new commissions are proposed at the ICA General Assembly, where delegates from the ICA member nations vote on whether to approve the proposals. Proposals for ICA commissions with US chairs to be considered at the 2019 ICA General Assembly include the following.

Table 1. Proposals for ICA Commissions with US Chairs for ICC 2019.

Commission	*Chair*	*Vice Chair*	*Cochairs*
Geospatial Analysis and Modeling	Xiaobai Angela Yao	Bin Jiang (Sweden)	
Geospatial Semantics	Dalia Varanka	Francis Harvey (Germany)	
History of Cartography	Imre Demhardt	Mirela Alti (Croatia)	
Map Design	Ian Muehlenhaus	Ken Field (Britain)	
Map Projections	Lynn Usery	Miljenko Lapaine (Croatia)	
User Experience (UX)	Rob Roth	Luciene Delazari (Brazil), Zdeněk Stachoň (Czech Republic)	
Visual Analytics			Anthony Robinson and Arzu Çöltekin (Switzerland)

US Entries in the International Cartographic Exhibition

The International Cartographic Exhibition (ICE) is held biennially in conjunction with the ICC. The USNC coordinates the entry of maps and other cartographic items from US mapmakers and others to be included in the ICE. The call for participation is open to all US cartographers and others to submit their cartographic products, including paper maps and charts, atlases, digital products, digital services, educational cartographic products, globes, and tactile maps. All submitted items must have been produced or modified after the date of the last ICC. Submissions are displayed in the ICE and in the online conference app. All submitted items are judged by a cartographic jury during the ICC, and winners are announced at the close of the ICC.

The 28th ICE was held in conjunction with ICC 2017 in Washington, DC, in July 2017. The 28th ICE featured a total of 475 maps, atlases, globes, and other cartographic works; among these were 44 entries from the United States, plus 2 from the US Geological Survey (USGS) and 18 from Esri. The entries from the United States included 33 maps on panels, 3 atlases, 4 digital products, 1 digital service, 3 charts, and 3 entries in the Other Cartographic Products category. The ICA judges selected the *Jenny Lake Hiking* map by Tom Patterson of the National Park Service as the third-place winner in the Map on Panels category, for which there were 307 entries. Esri's IFR Enroute Low Altitude—Alaska L-1 chart won third place in the Chart category.

The 29th ICE was held in conjunction with ICC 2019 in Tokyo, Japan, in July 2019. The USNC submitted 29 entries from the United States, plus 6 from USGS and 18 from Esri. The entries from the United States included 16 maps on panels, 3 atlases, 3 digital products, 3 educational products, and 1 entry in the Other Cartographic Products category.

US Entries in the Barbara Petchenik Children's World Map Drawing Competition

The Barbara Petchenik Children's World Map Drawing Competition is held every two years at the ICC. It was created by the ICA in 1993 as a memorial to Barbara Petchenik, who had a lifelong interest in maps for children and, unfortunately, died while in service to the ICA as a vice president on the association's executive committee (see Bevington-Attardi in this report). The aim of the contest is to promote children's creative representation of the world in graphic form. Entries are first selected in national competitions in all participating ICA member countries. The winning entries in the national competitions are then displayed during the ICC in an exhibition that is open to the public. Each nation can submit a total of six entries from children's contributions in the following age groups:

- Under 6 years of age
- Aged 6–8 years
- Aged 9–12 years
- Above 12 years of age

A panel of ICA judges select the winning entries in each of these age groups, and the exhibition visitors vote for a winner in the Public category.

In the ICC 2017 US national competition, all age groups were represented in the 37 maps: 5 maps in the Under 6 Years of Age category, 11 maps in the Aged 6–8 Years category, 13 in the Aged 9–12 Years category, and 8 in the Above 12 Years of Age category. These were displayed at the American Association of Geographers (AAG) conference in Boston, Massachusetts (April 10–14, 2017), where viewers were able to vote for their favorite entries. These votes helped the US judges determine which maps would be entered in the international competition. The six international finalists were from Illinois, Florida, Massachusetts, and Texas. Champ Turner, a 15-year-old male student from the Liberal Arts and Science Academy in Austin, Texas, won the Public Award in the international competition, in addition to first place in his age category.

For the ICC 2019 US national competition, there were 62 total entries: none in the Under 6 Years of Age category, 7 in the Aged 6–8 Years category, 14 maps in the Aged 9–12 Years category, and 15 in the Above 12 Years of Age category. At the AAG conference in Washington, DC, (April 3–7, 2019), the six international finalists were chosen, again in part by taking into account the public votes. The results of the international competition will be posted on the ICA website (https://icaci.org/petchenik/).

USNC Travel Funding

For each ICC, the USNC provides travel funding to help American and international scientists and scholars at US institutions attend. Support is based on a competitive evaluation of submitted materials, including an abstract and a short curriculum vitae. The number of applicants supported and the amount of support they receive are contingent on available funds. Preference is given to early career scholars (ECSs), who are defined as graduate students and those completing their PhD in the last five years. Support for non-ECSs is also available, with preference given to CaGIS members. Travel funding is contingent on acceptance of abstracts by the ICC 2019 organizing committee.

For ICC 2017 and ICC 2019, the USNC travel funding was provided by CaGIS and through a grant from the National Science Foundation (NSF). The NSF grant monies were used to fund ECSs, and the CaGIS contributions were used to support non-ECSs. Dr. Michael Leitner wrote the NSF grant for ICC 2017, and Dr. Patrick Kennelly wrote the NSF proposal for ICC 2019.

For the ICC 2017, the USNC received a total of 33 requests for travel funding from ECSs and 19 requests from non-ECSs. The USNC supported a total of 48 US participants in the 2017 ICC—31 ECSs were awarded $1,000 each, and 17 non-ECSs were awarded $500 each.

For the ICC 2019, the USNC received a total of 25 requests for travel funding from ECSs and 14 requests from non-ECSs. The USNC supported all 39 people who requested funding. The ECSs were awarded $2,000 each, and the non-ECSs were awarded $1,200 each.

Summary

The USNC provides many important functions in support of US cartography and participation of the US cartographic community in activities of the ICA. To learn more about the activities of the committee, visit https://cartogis.org/usnc-ica/.

Summary of Activities of the Cartography and Geographic Information Society

Daniel G. Cole

Smithsonian Institution, IT Office, MRC 136, Washington, DC 20013-7012, coled@si.edu; past president of CaGIS

Keywords: CaGIS, AutoCarto, Map Design Competition, CaGIS scholarships, COGO

Abstract

This is a summary of the activities conducted by the Cartography and Geographic Information Society (CaGIS) from 2016 to 2019. This review includes the biennial AutoCarto conference, the annual CaGIS Map Design Competition and Student Scholarship competition, the occasional Distinguished Career Award, the ongoing participation with the Coalition of Geospatial Organizations (COGO), the current involvement with American Society of Photogrammetry and Remote Sensing (ASPRS) on the State of Geospatial Employment Survey, and the hosting of the 2017 International Cartographic Conference.

AutoCarto 2016

The 21st International Research Symposium on Computer-based Cartography and GIScience was held in Albuquerque, New Mexico, USA, from September 14 to 16. The conference organizing committee received 42 abstracts that were reviewed by at least three program committee members. Authors of 36 of the 42 abstracts were invited to submit full papers to be published in the conference proceedings (Freundschuh 2016). Twenty-one authors submitted full papers that were reviewed and edited by the editor, and 10 authors submitted abstracts only.

In addition to paper presentations, two workshops sponsored by commissions of the International Cartographic Association were held during AutoCarto 2016—one titled "Teaching Map Projections" and the other on open-source geospatial technologies. The 2016 conference also included a poster session and was followed by a workshop titled "New Developments in Cloud-based Mapping."

AutoCarto 2018

AutoCarto 2018 was held jointly with the University Consortium for Geographic Information Science (UCGIS) at the historic Madison Concourse Hotel in Wisconsin, from May 22 to 24. This was the second time that the UCGIS Conference and AutoCarto Symposium had been colocated, the first being in 2006 in Vancouver, Washington.

The conference organizing committee received 1 position paper and 26 extended abstracts both for presentation at the conference and publication in the *Cartography and Geographic Information Science (CaGIS)* journal. Twenty-three abstracts were submitted for presentation only, 3 abstracts for lightning talks, 3 abstracts for poster presentations, and 14 abstracts for the student poster competition. Each submission was reviewed by at least two program committee members. Of these 70 abstracts, 24 were accepted as full papers for presentation at the conference, 8 papers were accepted for review and publication consideration in the CaGIS journal, 7 abstracts were accepted as lightning talks, 3 abstracts were accepted as poster presentations, and 8 abstracts were accepted for the student poster competition.

The theme of this conference was "Frontiers of Geospatial Data Science." Presentations and discussions centered around connections between geospatial science and the burgeoning field of data science seen, for example, in newly named academic departments and in calls for funded research. At this event, emerging opportunities and challenges for the geospatial and mapping sciences were explored with an eye on trends in deep learning, data-intensive computing platforms, and visualization, as well as geospatial big data sources and applications such as location-aware social media, autonomous vehicles, and Earth-observing micro- and nanosatellites and sensors (Freundschuh and Sinton 2018).

Topics in the special issue of the *CaGIS* journal that contained selected papers presented at the conference included mapping social media data, mobile mapping, 3D mapping tools, interoperability, spatial flow algorithms, volunteered geographic information, geographic ontologies and geographic features, mapping and natural hazards, geovisualization and education, and research questions dealing with large databases (Sinton et al 2019). For more information, see https://cartogis.org/autocarto/.

CaGIS Map Design Competition

Every January, CaGIS receives numerous printed and digital maps that were completed or published in the prior year as entries in the Annual Map Design Competition. The society awards certificates, $500 cash prizes, and MAPublisher software to winning students of the David Woodward Award for Best Digital Map and for the Arthur Robinson Award for Best Print Map, along with honorable mentions to a number of other student entrants. CaGIS gives a certificate of award to the Best of Show (fig. 1) and in the professional categories of Reference, Thematic, Book/Atlas, Recreation/Travel, Interactive Digital, and Other, along with honorable mentions to some other entrants. Notably, this competition has been held continually for the past 46 years. For more information, see https://cartogis.org/award/map-design-competition/.

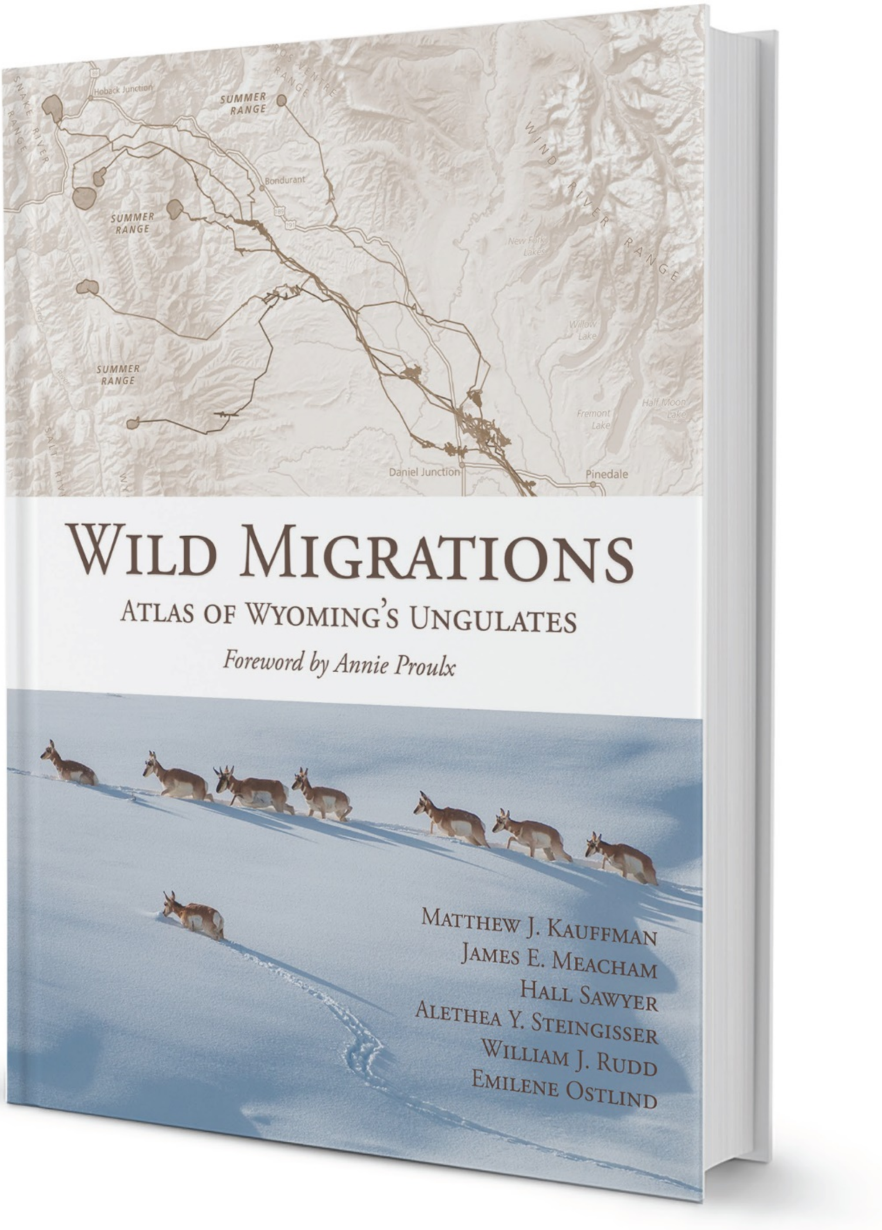


Figure 1. Best of Show in the 2018 CaGIS Map Design Competition.

CaGIS Scholarships

Each year, students may apply for CaGIS scholarships, which are awarded to candidates who have demonstrated excellence in cartography or GIScience coursework and the potential to contribute to cartography or GIScience research. Two outstanding master's students each receive $750, and one outstanding doctoral candidate receives $1,500. Winners of both awards are invited to submit their research at an upcoming CaGIS-sponsored conference (such AutoCarto) and may be eligible for limited travel or registration support if they choose to present at the event. For more information, see https://cartogis.org/award/the-cagis-student-scholarships/.

Distinguished Career Award

The CaGIS Distinguished Career Award is intended to honor the accomplishments of senior professionals who have contributed substantially to advancements in the fields of cartography or GIScience or at the interface between cartography and GIScience. Since 2016, CaGIS has given out two Distinguished Career Awards, one to Tim Trainor, formerly of the US Census Bureau, and the other to Michael Dobson of TeleMapics (fig. 2). These were the fourth and fifth recipients of the award, respectively, since its inception in 2008. For more information, see https://cartogis.org/distinguished-career-award-recipients/.

Figure 2. Recipients of the CaGIS Distinguished Career Award include Tim Trainor (left) and Michael Dobson (right).

Coalition of Geospatial Organizations

The Coalition of Geospatial Organizations (COGO) is a coalition of 13 national professional societies, trade associations, and membership organizations in the geospatial field, representing more than 170,000 individual producers and users of geospatial data and technology. Members include CaGIS, ASCE, ASPRS, AAG, GISCI, GLIS, IAAO, MAPPS, NSGIC, NSPS, UCGIS, URISA, and USGIF. The stakeholder groups that make up COGO speak with one voice on geospatial data and policy issues wherever possible. In accordance with its operating procedures, COGO only takes public policy positions when it has achieved a unanimous vote from its member organizations. To learn more about COGO, see http://cogo.pro/Home_Page.html.

The Report Card on the US National Spatial Data Infrastructure summary is online, and the CaGIS executive director, Scott Freundschuh, was the lead author on this report. For background, see the report at http://cogo.pro/uploads/2018COGOReportCard.pdf, http://cogo.pro/uploads/COGO_ReportCard_PressRelease_20190204.pdf, and http://cogo.pro/uploads/COGO_2018_Report_Card_slides_for_publicity_20190204.pdf.

State of Geospatial Employment Survey

In spring 2019, ASPRS and CaGIS distributed the first ever State of Geospatial Employment Survey. This survey will be the largest survey of its kind providing valuable data on the state of geospatial employment, compensation, and ideology across different countries, professions, and types of employers. People can participate in this historic survey at https://www.surveymonkey.com/r/CNGVKW5.

International Cartographic Conference 2017 (ICC2017)

CaGIS is the United States adherent to the International Cartographic Association (ICA). When the ICA was first formed in June 1959, the United States was one of 13 founding member nations. In 1978, CaGIS hosted the 9th International Cartographic Conference (ICC), which was held in College Park, Maryland. At that time, CaGIS was known as the

American Cartographic Association, a division of the American Congress on Surveying and Mapping. In 2017, CaGIS hosted the 28th ICC in Washington, DC, from July 2 to 7.

The Local Organizing Committee (LOC) was led by conference chair E. Lynn Usery along with cochairs Aileen Buckley and Tim Trainor. Cynthia Brewer served as the Scientific Program director, and Matt Rice served as chair of the Local Arrangements Committee. Eric Anderson, then executive director of CaGIS, also played a leading role in organizing and managing ICC2017. Other responsibilities fell on David Alvarez, who organized the workshops; Sven Fuhrmann, who was in charge of technical tours; Margaret Pearce, who was chair of the International Cartographic Exhibition; Paul Young, who was in charge of the budget; Michael Peterson, who was in charge of publications; Rob Edsall, who oversaw the exhibitions; and Rakesh Maholtra, who was in charge of the student program.

ICC2017 began with preconference workshops that convened in the four days prior to the opening of the conference on Monday, July 3. An Extraordinary General Assembly of national delegates to the ICA was held on Sunday, July 2. After the ICC2017 opening ceremony, the exhibition hall—which included the International Trade Exhibition and the International Cartographic Exhibition—was opened to the public, as was the area with the maps that had been entered in the Barbara Petchenik Children's World Map Drawing Competition. The Scientific Program began on Monday afternoon and included 10 concurrent sessions focused on a selection of the 40 conference themes. The week continued with each day consisting of parallel technical sessions of paper and poster presentations, as well as a special plenary presentation. Business meetings of the ICA commissions were also scheduled throughout the week, as were technical tours and a variety of social events. ICC2017 ended with the closing ceremony on the afternoon of Friday, July 7, during which a variety of ICA awards were announced. To learn more, see https://icaci.org/ica-awards-ceremony-icc2017dc/ and https://icaci.org/files/documents/newsletter/ica_news_69_2017_2_lq.pdf

References

Freundschuh, S. M., ed. 2016. *Proceedings of AutoCarto2016, 21st International Research Symposium on Computer-based Cartography*, *14–16 September 2016.* Albuquerque, New Mexico, USA.

Freundschuh, S. M., and D. Sinton, eds. 2018. *Proceedings of AutoCarto/UCGIS 2018, 22nd International Research Symposium on Computer-based Cartography, 22–24 May 2018.* Madison, Wisconsin, USA.

Sinton, D., S. Freundschuh, and N. Chrisman, coeditors. "Frontiers of Geospatial Data Science. AutoCarto." Special issue, *Cartography and Geographic Information Science.* 46:1, 1, https://doi: 10.1080/15230406.2019.1524665.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

Cartography and Geographic Information Science: An International Journal

Nicholas Chrisman

Editor, Cartography and Geographic Information Science*, Bellingham, Washington, USA*

Keywords: Scientific publication, Peer review, Special issues, Impact metrics

Abstract

The journal *Cartography and Geographic Information Science* provides a service to the international cartographic community. Due to the volunteer efforts of hundreds of reviewers, the journal maintains a high standard of peer review. Over the past four years, the journal has published 145 articles by 420 authors from 32 countries. As of 2019, the journal is no longer an official journal of the International Cartographic Association (ICA).

Introduction

The journal *Cartography and Geographic Information Science* (*CaGIS*) has provided service to the international cartographic community. Originally established in 1974 as *The American Cartographer,* it has grown over the years in its number of pages and in its impact around the world. This article covers the publication years 2016–2019, publication being typically ahead of the calendar year. Volume 43 was the last year with five issues; afterward, *CaGIS* shifted to six issues per year. In these four volumes of the journal, 145 peer-reviewed articles appeared. Each year the journal published around a hundred authors, representing a total of 33 countries. The yearly figures (table 1) show the persistent diversity of countries and authors.

Table 1. Publication details by volume (year). Note that individual authors may be counted multiple times; the figure is the sum of the authors of the peer-reviewed papers in a given year. Countries also are counted by year.

Volume (Year)	*Articles published*	*Authors contributing*	*Countries represented*
43 (2016)	31	100	16
44 (2017)	39	118	20
45 (2018)	38	111	15
46 (2019)	37	91	16

Over the four-year period, 58 papers came from US institutions and authors, while 52 came from European sources (taking Europe as a region, not a political entity). The rest of the papers include 17 from China and 18 from other countries (including Australia and Canada). This geographic distribution is not unusual in scientific publication. Africa, South America, and much of Asia are sorely underrepresented. Still, these figures demonstrate that the journal has a substantial international character.

While the number of pages and, thus, the number of articles published have remained fairly stable, the number of submissions has risen consistently. The result is that the journal has become more selective. Currently the acceptance rate is around 30 percent. Many manuscripts are rejected quickly because they do not fit the scope and purpose of the journal.

Peer Review and Impact Metrics

Those manuscripts that do fit the scope of the journal pass into the peer-review process. The journal depends on the unpaid expertise of a worldwide network of reviewers. In the last issue of each volume, the editor thanks the reviewers from the past year (annually, on 1 July). For 2018, there were 281 reviews performed by 198 individuals (Chrisman 2018). Without this dedicated effort, the whole process would not be possible.

Any literature passes from the author to the reader upon publication. It is important to consider not only where the paper originates but also where it goes. At one time, this journal was printed on paper and mailed to the members of the

Cartography and Geographic Information Society and a few academic libraries. People joined the society to get access to the journal. As the modes of publication have changed, access has been greatly expanded. In 2013, the society chose to move from publishing the journal itself to working through a commercial press, Taylor & Francis Group. Consequently, readership has expanded. This move has allowed the journal to see an increase in the measures used to monitor the impact of scientific publication. Typically, these involve counting citations in other peer-reviewed literature. Judging by these measures, the journal has attained an impact factor that is higher than those of journals that are strictly cartographic, and is similar to those of geographic information science (GIScience) journals. Impact factors vary by discipline—depending on norms and expectations regarding citation—so a journal like *CaGIS*, caught on some interdisciplinary boundaries, may not provide strict comparability. The commercially relevant impact factor reports consider just a two-year window of publication in a one-year period of citation. *CaGIS* has papers that continue to be cited after 45 years, since our discipline is more deliberative and historically conscious than some others.

Increases in the impact factor lead to more submissions, which lead to higher rejection rates. If properly tuned, the peer-review process allows a journal to improve. The cycle is positive, if the goal is the highest quality of papers.

Highlights and Special Issues

In four years, any journal will cover many subjects, and it will not always be clear which topics will be most relevant in 25 years. Professor Waldo Tobler (1976) talked about the half-life of analytical cartography curriculum in the journal. In 2018, Tobler (2018) published his last paper in issue 45(3), and he performed his last review for the journal just two weeks before his death. The journal noted his passing with an obituary (Clarke, 2018) and the cover of issue 45(4), with a composite graphic of the disparate themes of his work, his hyperelliptical projection in the background.

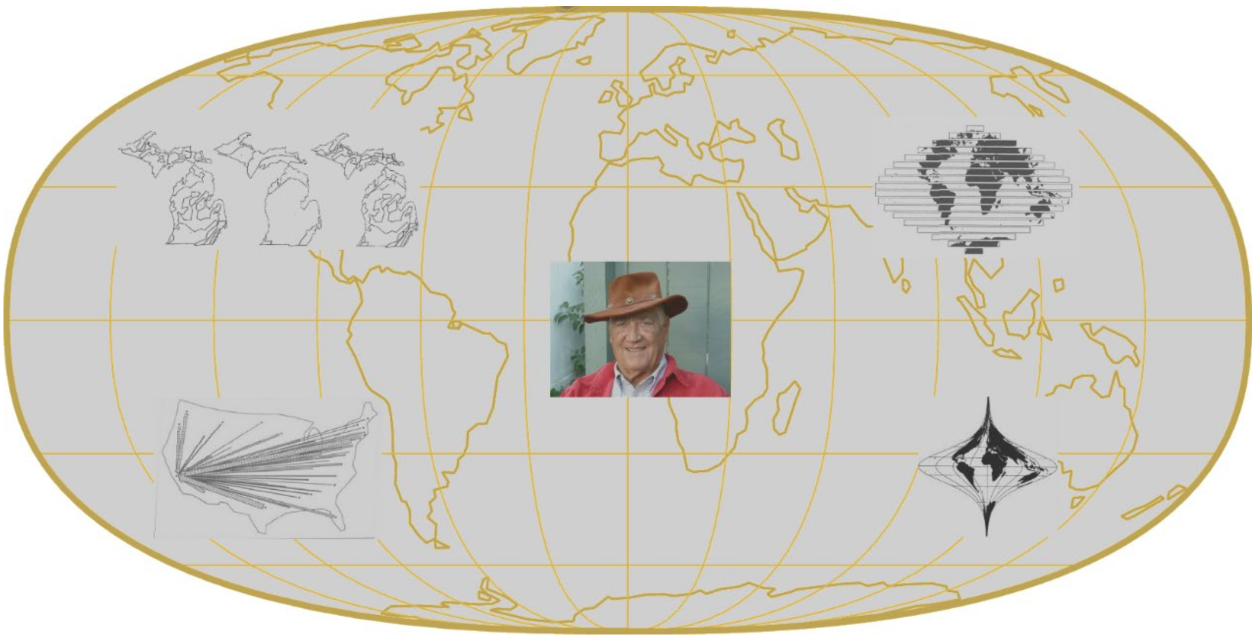


Figure 1. Composite graphic from cover of memorial issue 45(04), marking the death of Waldo Tobler

Also, during this period, *CaGIS* provided a means to publish dynamic and 3D illustrations for journal articles. Only a few have been published so far, but the journal has provided the means to present maps that move. The journal maintains its focus on providing the highest quality output in the print edition. Professor Thomas Hodler has reviewed the graphics on all papers published in the journal for many years. His dedication to the discipline deserves recognition.

The journal has changed in other ways. The review of literature has been dropped, since Internet search engines provide a more flexible means to explore the vast scientific literature. The journal has usually produced the US National Report to the International Cartographic Association (ICA) as a special issue. In 2015, the report was a supplement that was published online only. However, that solution was not considered adequate for many reasons. For 2019, one peer-reviewed open-access article appears in issue 46(3) with an editorial pointing to the ICA website for the full body of the online portion of the report.

In 2015, the journal participated with other cartographic journals in providing peer-reviewed papers related to the International Cartographic Conference (ICC) in Rio de Janeiro. This journal managed to accept and publish these papers in time for that cartographic congress. In 2017, the timelines of publication did not match the due dates for the ICC. A special issue, 46(2), covered papers regarding the 50th anniversary of Jacques Bertin's major book. These papers began as a session at ICC 2017. As the ICA publication procedures change, this journal will have less engagement in the proceedings of the meetings.

Relationship of the Journal to ICA

For decades, the journal has proclaimed itself "Official Journal of the International Cartographic Association" on its cover. The original basis for that declaration is lost in the mists of time. In 2018, ICA altered that status unilaterally without discussion, giving three affiliate journals that status. Consequently, the Cartography and Geographic Information Society has decided to remove the declaration of official status. The society is the member organization of ICA for the United States. While the journal may no longer be official, it retains its role in service to the international community of cartographers.

References

Chrisman, Nicholas. 2018. "Thanks to Reviewers: 1 July 2017–30 June 2018." *Cartography and Geographic Information Science* 45:6, 570. doi: 10.1080/15230406.2018.1497919.

Clarke, Keith C. 2018. "Waldo R. Tobler (1930–2018)." *Cartography and Geographic Information Science* 45:4, 287–288. doi: 10.1080/15230406.2018.1447399.

Tobler, W. R. 1976. "Analytical Cartography." *The American Cartographer* 3:1, 21–31. doi: 10.1559/152304076784080230.

Tobler, Waldo. 2018. "A New Companion for Mercator." *Cartography and Geographic Information Science* 45:3, 284–285. doi: 10.1080/15230406.2017.1308837.

The Twenty-Eighth International Cartographic Conference: ICC 2017

Kari Craun [a, *], Aileen R. Buckley [b], and Daniel G. Cole [c]

[a] *US Geological Survey, National Geospatial Technical Operations Center, kcraun@usgs.gov*
[b] *Esri, 380 New York Street, Redlands, CA 92373, abuckley@esri.com*
[c] *Smithsonian Institution, IT Office, MRC 136, Washington, DC 20013-7012, coled@si.edu*

* Corresponding author

Keywords: International Cartographic Conference (ICC), International Cartographic Association (ICA), Cartography and Geographic Information Society (CaGIS), International Cartographic Exhibition (ICE), Barbara Petchenik Children's World Map Drawing Competition

Abstract

The Twenty-Eighth International Cartographic Conference (ICC) was held July 2–7, 2017, at the Marriott Wardman Park Hotel in Washington, DC, with attendees and exhibitors representing an international assembly of governments, academia, and private industries. This is the second time that the conference was held in the United States, the first being the 9th ICC in College Park, Maryland, over 20 years earlier (1978). This article summarizes the organization of ICC 2017 and the main events that occurred there.

Introduction

As the official conference of the International Cartographic Association (ICA), the ICC takes place every two years in one of the ICA member nations, where it is organized and sponsored by national societies or agencies. The Twenty-Eighth ICC (ICC 2017) was organized and sponsored by the Cartography and Geographic Information Society (CaGIS), the US adhering body to the ICA. ICC 2017 was held July 2–7, at the Marriott Wardman Park Hotel in Washington, DC, with attendees and exhibitors representing an international assembly of governments, academia, and private industries (fig. 1). This is the second time that the conference was held in the United States, the first being the 9th ICC in College Park, Maryland, over 20 years earlier (1978).

Figure 1. Conference attendees gathered for the opening plenary session for ICC 2017. (Photo by Eric Anderson.)

Conference Organization

The Local Organizing Committee (LOC) was led by conference chair E. Lynn Usery along with cochairs Aileen Buckley and Tim Trainor (Usery et al. 2017). Cynthia Brewer served as the Scientific Program Committee director and Matt Rice served as chair of the Local Arrangements Committee. Eric Anderson, then-executive director of CaGIS, also played a leading role in organizing and managing ICC 2017. Other responsibilities fell on David Alvarez, who organized the workshops; Sven Fuhrmann, who was in charge of technical tours; Margaret Pearce, who was chair of the International Cartographic Exhibition; Paul Young, who was in charge of the budget; Michael Peterson, who was in charge of publications; Rob Edsall, who oversaw the exhibitions; and Rakesh Maholtra, who was in charge of the student program.

Although ICC 2017 was primarily organized and sponsored by CaGIS, corporate sponsors included Hemisphere level (US$10,000) sponsorships by the US Geological Survey (USGS), US Census Bureau, Esri, and GOESS/Afriterra.

Overview of Events

ICC 2017 was preceded by workshops of commissions of the ICA that convened four days prior to the opening of the conference. The Extraordinary General Assembly of delegates to the ICA was held on Sunday, July 2. ICC 2017 officially began the next day with an opening ceremony that had an audience of around 900. The program included special presentations by Menno-Jan Kraak, ICA president, and Kari Craun, director of the USGS National Geospatial Technical Operations Center; a number of welcomes from the American cartographic community; and a musical program by the award-winning Howard University Gospel Choir (fig. 2), which also performed the ICA anthem (introduced at ICC 2015 in Rio).

Figure 2. The Howard University Gospel Choir performed a short but enthusiastic musical program during the ICC 2017 opening ceremony on July 3. (Photo by Dierdre Bevington-Attardi.)

After the opening ceremony, the exhibition hall, which included the International Trade Exhibition and the International Cartographic Exhibition, was opened to the public, as was the area with the maps that had been entered in the Barbara Petchenik Children's World Map Drawing Competition. The scientific program began on Monday afternoon and included concurrent sessions on a wide selection of conference themes. An icebreaker reception was held in the exhibition hall later that evening, allowing conference attendees to mix and mingle over drinks and a healthy offering of appetizers (fig. 3).

The week continued with each day consisting of concurrent paper sessions, poster presentations, and plenary sessions. Business meetings of the ICA commissions were also scheduled throughout the week, as were technical tours and a variety of social events. ICC 2017 ended with the closing ceremony on the afternoon of Friday, July 7, during which a variety of ICA awards were announced (http://icaci.org/ica-awards-ceremony-icc2017dc/). Additionally, the conference's student assistants offered their insight into the conference, and a wrap-up presentation was given by Kraak. During the ceremony, the organizers officially received the ICA flag for the next ICC, to be held in 2019 in Tokyo, Japan (http://icaci.org/icc2019/).

Details about these and other ICC 2017 events follow. See also https://icaci.org/files/documents/newsletter/ica_news_69_2017_2_lq.pdf.

Highlights

Highlights of ICC 2017 included the following:

- Just over 900 registrants from 57 countries, including 316 registrants from the United States
- 28 student volunteers from 9 countries
- 496 scientific paper presentations and 205 poster presentations, 116 and 27 entries, respectively, were from the United States
- The International Cartographic Exhibition with 475 maps, atlases, globes, and other cartographic works, including 66 entries from the United States, 2 of which were from the USGS and 18 were from Esri
- The Barbara Petchenik Children's World Map Drawing Competition with 193 entries from 34 countries, including 6 entries from the United States (fig. 2)
- Plenary presentations from Tom Patterson, US National Park Service; Robert Cardillo, director, National Geospatial-Intelligence Agency; Lee Schwartz, geographer, US Department of State; and Mikel Maron, Mapbox
- 12 preconference workshops with 271 attendees
- 10 technical tours with 230 attendees
- An icebreaker reception on the evening of the opening day
- A gala dinner at a Texas-style restaurant (fig. 3)
- An orienteering event with 33 participants

Figure 3. Conference participants attended the gala dinner at Texas Hill Country Barbeque. (Photo by Eric Anderson.)

Scientific Program

The scientific program (http://icc2017.org/conference-program/) was developed from more than 763 abstracts and papers submitted to the ICC LOC (http://icc2017.org/icc-2017-local-organizing-committee/). Under the direction of Brewer (fig. 4), nearly 80 members of the Scientific Program Committee (see page 5 of the print program at http://www.eventscribe.com/2017/ICC/assets/AbridgedProgramPDF.pdf) organized papers and posters for sessions relating to the 40 conference themes. Oral presentations were given in over 10 daily concurrent sessions held July 3–7. Poster sessions were held July 3–5.

Figure 4. Scientific Program Committee chair Cindy Brewer worked hard to make sure the program was up-to-date. (Photo by Dierdre Bevington-Attardi.)

The program also included a series of plenary presentations (http://icc2017.org/keynote-presentations/) from the following:

- Tom Patterson, senior cartographer for the US National Park Service, on Tuesday
- Robert Cardillo, director of the US National Geospatial-Intelligence Agency, on Wednesday
- Lee Schwartz, geographer of the US Department of State, on Thursday
- Mikel Maron, data team member of Mapbox, on Friday

International Cartographic Exhibition

In conjunction with each ICC, the ICE is organized, wherein map products originating from ICA member nations and affiliate members are displayed. The maps in the exhibition are first authorized and selected by the ICA national or affiliate members. At the ICE, an international jury selects the best entries in various categories. As with the papers and posters, the entries in the ICE can be searched for and viewed in the online program or via the web app: (https://www.eventscribe.com/2017/ICC/PosterTitles.asp?h=International%20Cartographic%20Exhibition).

The 475 total entries in the 28th ICE included the following:

- 289 maps on panels
- 44 digital cartographic products
- 43 charts on panels

- 41 atlases
- 24 educational cartographic products
- 24 other cartographic products
- 9 digital services

The United States had 44 entries in the International Cartography Exhibition, including 33 maps on panels (fig. 5), 3 atlases, 4 digital products, 1 digital service, and 3 entries in the Other Cartographic Products category.

Figure 5. The US paper maps were displayed on six panels in the International Cartographic Exhibition; one full panel is shown here. (Photo by Dierdre Bevington-Attardi.)

The judges selected the Jenny Lake Hiking map, by Tom Patterson of the National Park Service, as the third-place winner in the Map on Panels category. Esri's IFR Enroute Low Altitude—Alaska L-1 chart won third place in the Chart category.

Barbara Petchenik Children's World Map Drawing Competition

The Barbara Petchenik Children's World Map Drawing Competition is a biennial cartographic competition for children. It was initiated by the ICA in 1993 as a memorial to Barbara Petchenik, who had a lifelong interest in maps for children. Petchenik died while in service to the ICA as a vice president on the executive committee.

The aim of the contest is to promote children's creative representation of the world in graphic form. Entries are first selected in a national competition in all participating ICA member countries. The winning entries in the national competitions are then exhibited during the International Cartographic Conference (fig. 6), where the international winners are selected (see https://icaci.org/petchenik/ for a list of past winners). The 2017 competition included entries from 34 participating countries and 193 drawings categorized in the following age groups (see https://childrensmaps.library.carleton.ca/ for images of the past entries):

- Under 6 years of age (16 submissions)
- 6–8 years of age (29 submissions)
- 9–12 years of age (75 submissions)
- 12–16 years of age (73 submissions)

Figure 6. The United States entered six national winners in the Children's Map Competition (top, left to right): Painting the World a New Picture; Colorful Earth Puzzle; We Love Maps: Food for Thought; (bottom, left to right) A Bird's-Eye View, Earth—A Fascinating Place Deep, Deep inside the Milky Way; Maps: Our Path for Exploration. (Photo by Dierdre Bevington-Attardi.)

The map by Champ Turner from the US won the public award, which is decided by a vote of all participating visitors to the exhibition. He was able to receive this award in person as he had traveled with his mother from Texas to Washington, DC, to see the exhibition (fig. 7).

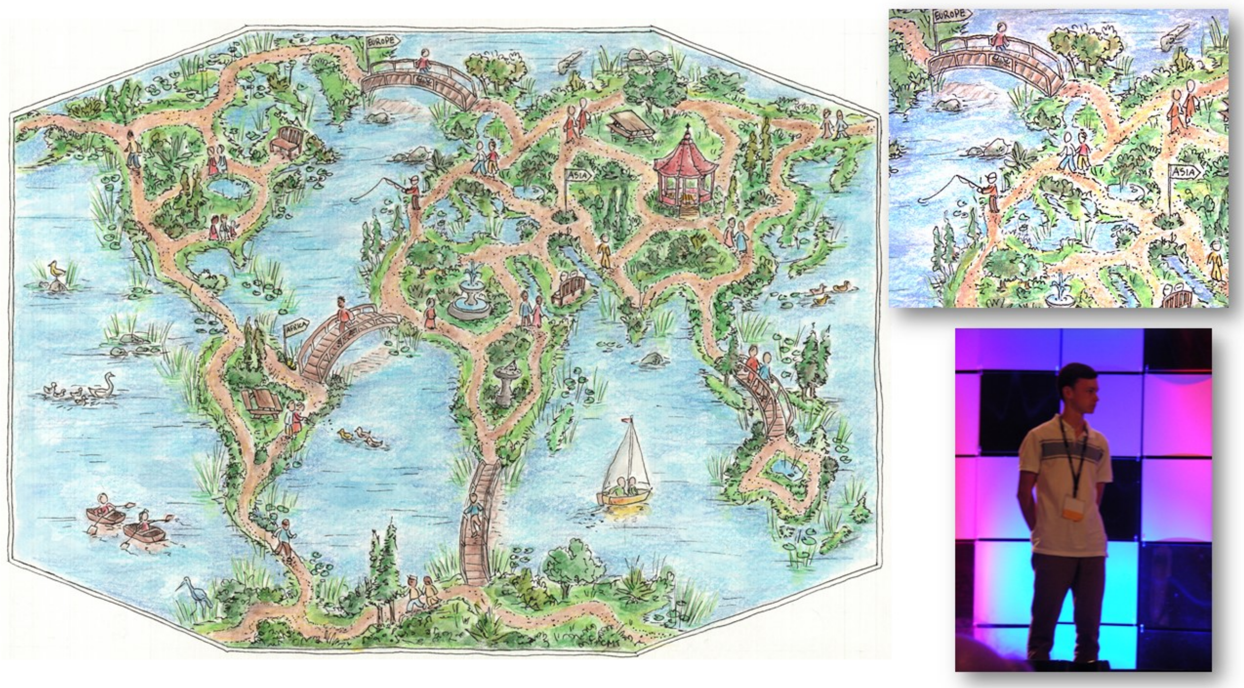


Figure 7. Champ Turner accepted his award in person after having traveled with his mom to ICC 2017 to see the children's map exhibition. (Photo by Dierdre Bevington-Attardi.)

International Trade Exhibition

The International Trade Exhibition was open to conferencegoers July 3–6, with 25 exhibitors representing federal agencies, private industries, universities, publishers, and professional societies from around the world. A special booth gave visitors a glimpse of what to expect at ICC 2019 in Japan (fig. 8).

Figure 8. Visitors to the International Trade Exhibition could learn about what to expect at ICC 2019 in Tokyo, Japan. (Photo by Linda Hill.)

Publication of Conference Submissions

A Springer book, *Advances in Cartography and GIScience: Selections from the International Cartographic Conference 2017*, was edited by Michael Peterson (fig. 9). For this book, Peterson selected 36 papers from the conference submissions based on reviewer ratings. The *International Journal of Cartography* editors published 12 of these papers. *The Cartographic Journal* and *Cartographica* also invited submissions from among the remaining papers.

Conclusion

ICC 2017 provided a unique, weeklong opportunity for participants to immerse themselves in learning about scientific, technological, and societal developments in cartography and GIScience. These developments were expressed in papers and posters and in exhibitions of maps and technology. Washington, DC—the center of US cartography—proved to be an excellent venue for the events, and the many conference participants and exhibition visitors were presented with a myriad of opportunities to discover more about cartography and the host city each day of the conference.

References

Usery, E. Lynn, Aileen Buckley, Tim Trainor, Cindy Brewer, Matt Rice, Margaret Pearce, David Alvarez, Michael Peterson, and Eric Anderson. 2017. A Report to the International Cartographic Association and the Cartography and Geographic Information Society, unpublished manuscript.

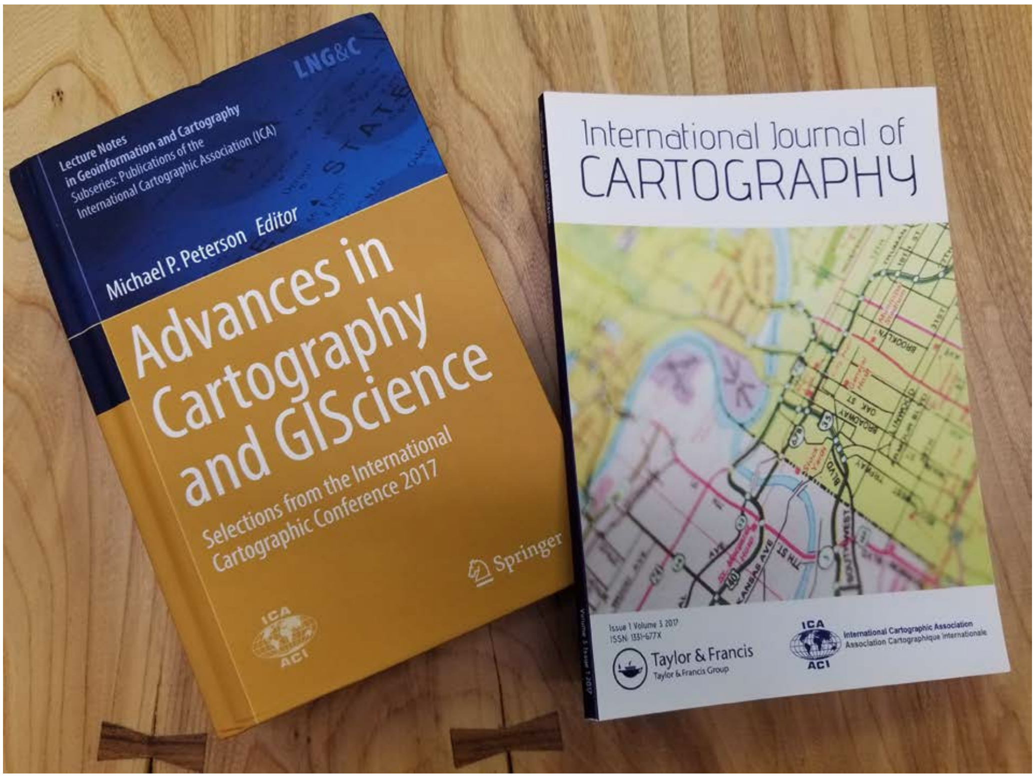


Figure 9. These publications contain conference Track B paper submissions. (Photo by Lynn Usery.)

International Cartographic Association
Association Cartographique Internationale
Cartography and Geographic Information Society

For the Love of Maps: The Story behind the Barbara Petchenik Children's World Map Drawing Competition

Dierdre Bevington-Attardi

U.S. Census Bureau, dierdre.bevington.attardi@census.gov

Keywords: Barbara Petchenik, Children's maps, World, Cartography, ICA

Abstract

The International Cartographic Association (ICA) sponsors a biennial world map drawing competition for students from preschool to high school (ages 5–15). Hand-drawn representations of the world creatively interpret the competition theme, We Love Maps. This was the theme for the past two competitions (2017 and 2019), and it was inspired by the slogan for International Map Year, which ran from 2015 to 2017. In this article, the organizer for the 2019 US Children's Map Competition shares some thoughts about the competition, the kids' maps, and the woman who inspired The Barbara Petchenik Children's World Map Drawing Competition.

Introduction

Barbara Bartz Petchenik (1939–1992) believed in the power of maps to communicate "a larger, meaningful reality" (Petchenik 1987, 22). The International Cartographic Association's Barbara Petchenik Children's World Map Drawing Competition is the unwritten final chapter of her prolific cartographic career. Every world map that has been produced for this competition since 1993 is a unique, "almost miraculous" cartographic and artistic representation of the world from a child's point of view (Petchenik 1987, 22). Most recently, the ICA's Commission on Cartography and Children (founded in 1999) chose the theme We Love Maps, which was the slogan of the ICA-organized International Map Year (2015–2017) for the last two competitions (2017 and 2019), but the results have been far from repetitive.

The Competition's Theme: We Love Maps

Whatever the theme and however a child's meaningful reality is expressed, kids' maps are powerful. Using tabloid-size paper, crayons, pencils, and/or paint, kids aged 5 to 15 are invited to interpret the competition theme with a handmade rendering of the world. We Love Maps is typically translated as an appreciation of nature, food, books, sports, fun, and play. Aside from the more popular heart projection to represent love, kids have morphed world map projections into the shape of a fish, cow, superhero, or flying carpet. The creativity of these young mapmakers is apparent in the gentle rendering of the outlines of continents onto the face of a starving child (fig. 1). Stronger, more impactful emotions of wonder, discovery, hate, fear, tolerance, and political urgency have also appeared on these maps, uncovering a deep and abiding concern for a peaceful, healthy, and safe planet. A child's ability to communicate love in all these truly unique map projections all but eliminates the boundaries between the countries and cultures represented in this competition.

Figure 1. The map by Rebecca Kneale and Akira McTavish-Huriwai, titled *Through a Child's Eyes*, won second place in the 2017 New Zealand Children's Map Competition, and it was an international finalist in the 2017 Barbara Petchenik Children's World Map Drawing Competition. (Courtesy ICA.)

It is no surprise for teachers and parents that the Petchenik competition is an increasingly rare opportunity for kids to tell their story about the world, without the noise and assistance of digital devices, gaming templates, or social media. By default, participants learn about map projections, symbolization, line work, type, patterns, and color—not to mention geography! Each map is inherently cartographic in nature, though it is unlikely that many of these nascent mapmakers were trained in cartography per se. The knowledge, world experiences, and emotions of these young mappers have come alive in this manual, homegrown, and textural environment—and the scribbles, smudges, and patterns they have drawn are evidence of how freely these ideas emerge. Like words on a page, the competition's map treasures have a simple, raw lexicon to represent the voices and messages of individual map artists who ask hard-hitting questions—*What Are You Going to Do about It?* (fig. 2) is an example.

Unfortunately, Petchenik did not experience the ubiquitous digital mapping systems that have evolved since the early 1990s as her vibrant cartographic career ended with her death after a short illness in June 1992. Through her work, she certainly paved the way for young map audiences to increase their geospatial awareness and knowledge about the world. Ultimately, she inspired their love of maps by encouraging map publishers of all kinds to share meaning in the content and ideas represented on maps produced for children, by children.

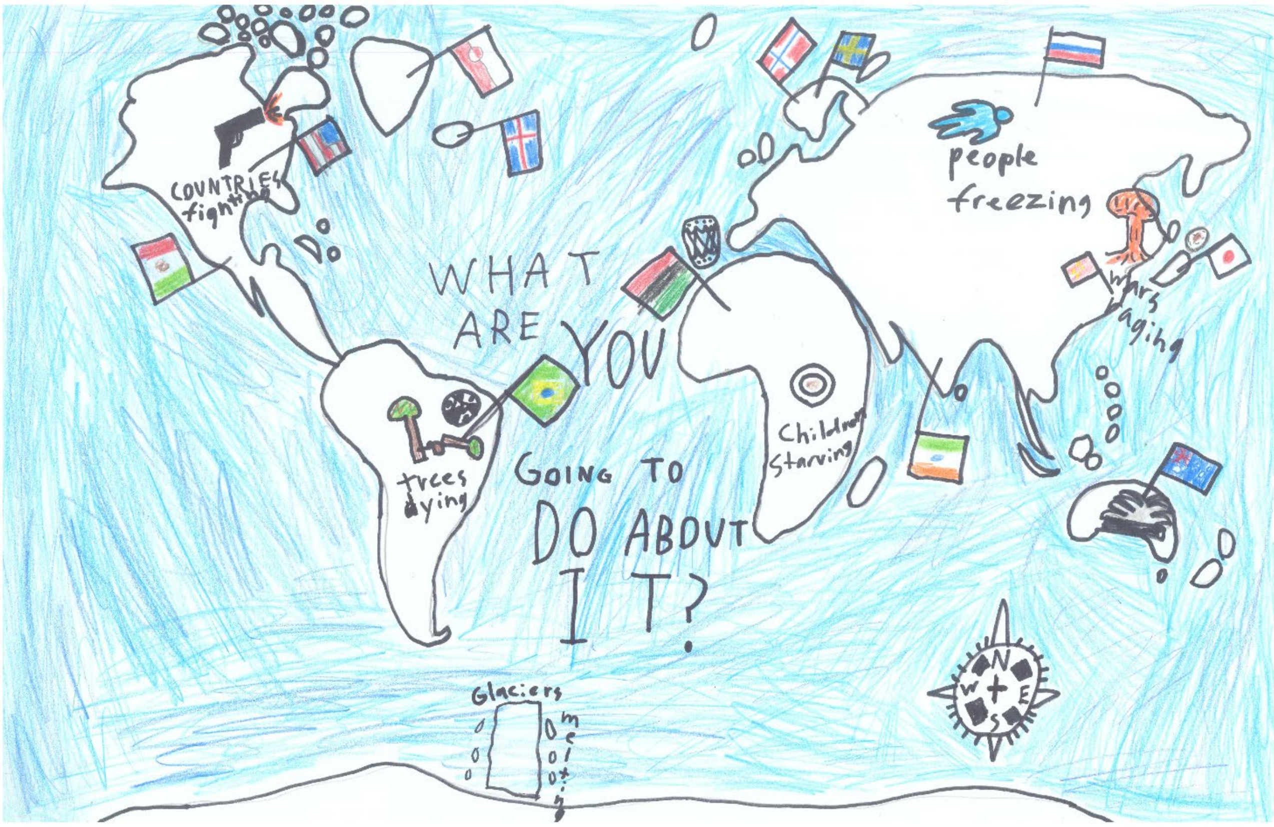


Figure 2. Lukas Hanson's map *What Are You Going to Do about It?* was the second-place winner in the Aged 9–12 Years category in the 2019 US Children's Map Competition, and it is an international finalist in the 2019 Barbara Petchenik Children's World Map Drawing Competition. (Courtesy ICA.)

A Children's Advocate for Meaningful Cartography

Petchenik's research and lifelong interest in maps for children promoted opportunities for kids to learn about the world in a structured way. She often wrote about maps that convey "meaning" and "factual integrity" and urged students to focus their observations on "content and ideas" (Petchenik 1987, 21). She was a pioneer in cartography at a time when women did not have a significant presence in commercial cartographic publishing or academic cartographic research. She attended the University of Wisconsin–Madison and earned a bachelor of science degree in chemistry and graduate degrees in geography with a doctorate in cartography and a minor in educational psychology (Morrison 1992, 60; Bartz 1970, 18). While completing her doctorate in 1969, she established her reputation in map design, producing maps and atlases in the *World Book Encyclopedia* for children age 9 to 14. Working from her home base in Chicago, she continued her cartographic consulting and editing career for Newberry Library, where she spent five years (1970–1975) working on hundreds of maps as coeditor for *Atlas of Early American History: The Revolutionary Era, 1760–1790* (Cappon 1976).

She joined the commercial Chicago-based map company R.R. Donnelley & Sons in 1975, where she spent the remainder of her career and continued her active involvement in the design, production, and sales of reference maps in encyclopedias and textbooks. In the meantime, while she balanced family, a demanding work travel schedule, and multiple committee memberships, Petchenik published over 50 articles, papers, and reviews on cartographic research topics, most notably her productive collaboration with friend and mentor Arthur Robinson on *The Nature of Maps* (1976). This work presented "a deeper understanding of the characteristics and processes by which the map acquires meaning from its maker and evokes meaning in its user—a general theory of cartography" (Robinson and Petchenik 1976, xi).

Petchenik accomplished many firsts as a distinguished woman in the field of cartography in the 1970s and 1980s, and she served in leadership roles in several professional organizations, including the International Geographical Union and the ICA. In 1991, Petchenik was the first woman to be elected to the ICA Executive Committee (EC). She served as a vice president for a short time before her death in 1992. The US appointed Judy Olson to the ICA EC to complete Petchenik's term as a vice president (until 1995). In 1993, the biennial Barbara Petchenik Children's World Map Drawing Competition was created by the ICA as a memorial to Petchenik's lifelong interest in maps for children (Dreki 2017).

Petchenik's wide-ranging professionalism also served the Society of Automotive Engineers, in which she was a member of the Committee for Automotive Navigational Aids. She was a member of the Mapping Sciences Committee of the National Research Council of the National Academy of Sciences and the principle author of the academy's first published report (Robinson 1994, 175). This report preceded a virtual explosion of geospatial data that contributes to the National

Spatial Data Infrastructure (NSDI) today. It presented familiar themes that persist in cartographic publications and open data legislation regarding the future spatial data needs of the United States within "the cartographic enterprise" (National Research Council 1990, 9). One can only imagine the kinds of conversations and innovations that Petchenik shared with her cartographic colleagues in the early 1990s after geographic information system (GIS) technology had taken "20 years to become an overnight success" (National Research Council 1990, 17). Car navigation systems, personal computing, mobile phones, and digital map products have been reformulated many times since. In this seminal report, Petchenik and others predicted that our modern world was moving toward a time when machines would be capable of assimilating data "in ways for which there is no human analogue" (National Research Council 1990, 18).

Now, 26 years after the establishment of the Petchenik Children's World Map Drawing Competition, kids have an almost rare opportunity to create a map by hand—with nothing more than a simple quest for meaning and with what today's cartographers would consider rudimentary instruments. We are the recipients of her remarkable cartographic legacy and the stewards of her mission to create meaningful cartography with every map produced for this competition.

Children's Map Competitions

The Petchenik Children's World Map Drawing Competition is a lasting credit to Petchenik's accomplishments as cartographer, teacher, and passionate advocate for children's maps. Every two years, each participating member country of the ICA organizes a national children's map drawing competition. Six winners are selected from each national competition, and these maps are entered and exhibited at the International Children's World Map Drawing Competition at the International Cartographic Conference (ICC), which takes place in a different host country every two years. The international winners are chosen by a panel of eight judges who represent cartographic professions from all over the world.

The United States Children's Map Competition is sponsored by the Cartography and Geographic Information Society (CaGIS) and the National Council for Geographic Education. The 2017 and 2019 competitions were held in Boston, Massachusetts, and Washington, DC, at the American Association of Geographers annual meetings. During these meetings, conference participants voted for maps in all four age categories: Under 6 Years of Age, Aged 6–8 Years, Aged 9–12 Years, and Above 12 Years of Age. Each age group was eligible for first-, second-, and third-place rankings and honorable mention. Schools in Chicago, Illinois, sent the most entries for the last three competitions—a strong showing of support from Barbara Petchenik's hometown. A student from Austin, Texas, won the Public Vote Award and first place in the Above 12 Years of Age category at the AAG meetings, and his entry was exhibited at the 2017 ICC in Washington, DC. The six finalists from the 2017 US Children's Map Competition were displayed alongside 33 other competing countries at the 2017 ICC.

In April 2019, the six finalists for the United States were chosen at the American Association of Geographers Annual Meeting in Washington, DC. The winners from the 2019 competition expressed a distinct sense of urgency about the earth's oceans and environment, survival, resiliency, and world peace. The winner of the Public Vote Award and first place in the Above 12 Years of Age category was a Burmese-American student from Dallas, Texas, for her map entitled *Fractures and Faults*, showing the world's biggest challenges' toll on humans and the environment. Maps with hard-hitting messages about saving and protecting animals, and warnings about what might happen if we don't change, are inexorably linked to the Petchenik concept of meaningful maps. An 11-year old's entry entitled *Map of a Woman* won the 2019 creativity award in the US competition. Lists of the national finalists and winners of the 2019 international competition at the ICC in Tokyo, Japan, as well as winners from past competitions (from 1993), are available from the Winner Map Collection at the Carleton University Library website (http://children.library.Carleton.ca/).

Conclusion

Whether you like pizza, snow globes, flowers, cats, candy, unicorns, meteor showers, or bubble gum, there is no shortage of creativity and meaning portrayed on the maps entered in the Barbara Petchenik Children's World Map Drawing Competition from the youngest generation of cartographers. Barbara Petchenik's career produced thousands of kid-friendly maps and challenged the cartographic community to do more to create meaningful maps for children. The thousands of kids' maps created for the national and international map drawing competitions have repaid her efforts in kind. Everyone in the business of discovering meaning on maps should encourage kids age 5 to 15 to enter this competition for the love of maps. Kids, parents, and teachers can look for future announcements about the international competition and rules on the ICA website (http://icaci.org/petchenik) and the NCGE and CaGIS website for future US competitions.

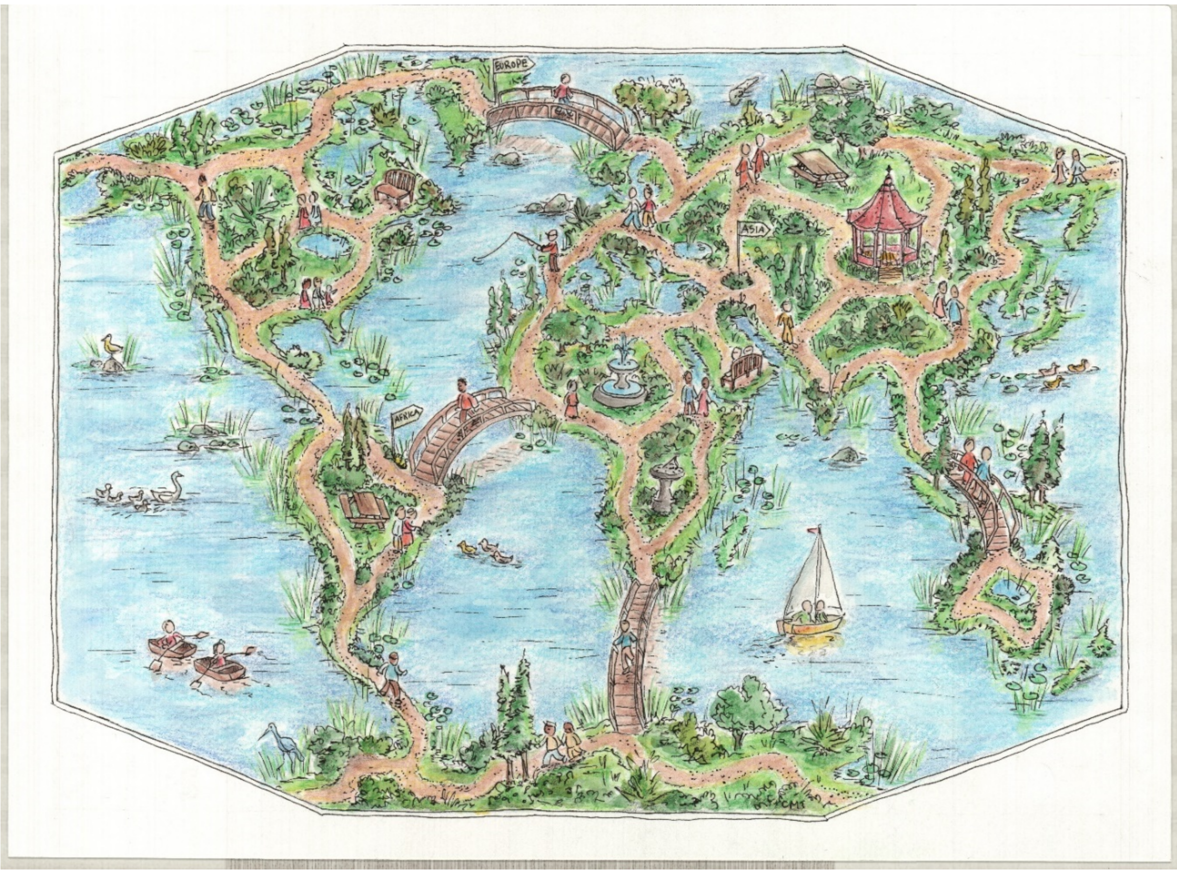


Figure 3. Champ Turner's map, titled *Our Path for Exploration*, won first place in the Above 12 Years of Age category and the Public Vote Award in the 2017 US Children's Map Competition. It was also an international finalist in the 2017 Barbara Petchenik Children's World Map Drawing Competition and won the Public Vote award for the international competition. (Courtesy ICA.)

References

Bartz, Barbara. 1970. "Maps in the Classroom." *The Journal of Geography* 69, no. 1: 18–24.

Cappon, Lester. *Atlas of Early American History: The Revolutionary Era, 1760–1790*. Edited by Barbara Bartz Petchenik and John Hamilton Long. Princeton, NJ: Princeton University Press, 1976.

Igor Dreki, ed. "Children Map the World." *ICA News* 68, 5. https://icaci.org/files/documents/newsletter/ica_news_68_2017_1_lq.pdf.

Morrison, Joel L. 1992. "Barbara Bartz Petchenik: In Remembrance." *Cartographica* 29, no. 2: 60.

National Research Council, Mapping Science Committee. *Spatial Data Needs: The Future of the National Mapping Program*. Washington, DC: National Academy Press, 1990.

Petchenik, Barbara. 1971. "Cartography for Children: A Research Approach." *La Revue de Geographie de Montreal* 25: 407–10.

Petchenik, Barbara. 1987. "Fundamental Considerations about Atlases for Children." *Cartographia monograph* 24, no. 1: 16–23.

Petchenik, Barbara. 1970. "Maps in the Classroom," *Journal of Geography* 69: 18–24.

Robinson, Arthur H. 1994. "B.B. Petchenik (1939–1992)." *Imago Mundi* 46: 174–175.

Robinson, Arthur H., and Barbara Bartz Petchenik. 1977. "The Map as a Communication System." *Cartographica* 14, no. 1: 92–110.

Robinson, Arthur H., and Barbara Bartz Petchenik. *The Nature of Maps: Essays toward Understanding Maps and Mapping.* Chicago: University of Chicago Press, 1976.

Taylor, D. R. Fraser. 1992. "Barbara Bartz Petchenik: In Remembrance." *ICA Newsletter* no. 2:7.

Report on UCGIS Activities, 2018 and 2019

Alberto Giordano [a, *], Karen Kemp [b], and Diana Sinton [c]

[a] *Department of Geography, Texas State University, San Marcos, TX, ag22@txstate.edu*
[b] *Spatial Sciences Institute, University of Southern California, Los Angeles, CA, kakemp@usc.edu*
[c] *Executive Director UCGIS, dianasinton@ucgis.org*

* Corresponding author

Keywords: Professional organization, UCGIS

Abstract

This article highlights some of the activities that the University Consortium for Geographic Information Science (UCGIS) undertook during 2018 and 2019, preceded by a brief introduction to the organization.

About the UCGIS

The UCGIS is a nonprofit, scientific and educational organization composed of over 65 member and affiliate institutions. It was established in 1995 to advance research in the field of geographic information science (GIScience), expand and strengthen multidisciplinary GIScience education, and advocate policies for the promotion of the ethical use of and access to geographic information and technologies by building and supporting scholarly communities and networks. UCGIS is the professional hub for the academic GIS community in the United States, with partnerships extending this capacity abroad. UCGIS offers opportunities for specialized training, career enhancement, and professional development for faculty and students. Such activities include its annual symposia (https://www.ucgis.org/symposia), coordination of National Science Foundation (NSF)-funded workshops and summer schools, and a webinar series, among others. Members have access to multiple channels of communication to remain current and voice opinions on national and international topics that impact our community such as pending legislation, ensuring open data and open software, and promoting the geospatial perspective in data science. UCGIS also serves as the developer and steward of the Geographic Information Science & Technology (GIS&T) Body of Knowledge (BoK) as an open resource (https://gistbok.ucgis.org/). For more information on UCGIS, see https://www.ucgis.org.

GIS&T Body of Knowledge

The GIS&T BoK documents the domain of geographic information science and its associated technologies. By providing this content in a new digital format, UCGIS aims to continue supporting the GIS&T higher education community and its connections with the practitioners, employers, and clients who comprise the increasingly diverse collection of professionals in this field. The digital version, first launched in 2016, was built directly from the original 2006 GIS&T Body of Knowledge. New and revised content is continually added. Many individuals and groups have contributed to this effort over the years, and we thank them for their hard work and dedication. In its new form as a peer-reviewed publication, we are particularly grateful that dozens of people every year serve as reviewers of draft entries. The BoK can be found at https://gistbok.ucgis.org/.

2018 UCGIS Annual Symposium

Under the direction of 2017–2018 president Shashi Shekhar, the 2018 UCGIS Annual Symposium was cohosted with the Cartography and Geographic Information Society (CaGIS) and held in Madison, Wisconsin, May 22–24. The joint AutoCarto and UCGIS symposium explored the frontiers of geospatial data science. Panelists and breakout groups considered the connections between geospatial science and the burgeoning field of data science. Attendees explored emerging opportunities and challenges for the geospatial and mapping sciences with an eye toward trends in deep learning, data-intensive computing platforms, and visualization, as well as geospatial big data sources and applications, such as location-aware social media, autonomous vehicles, and earth-observing micro- and nanosatellites and sensors. Selected papers presented at the symposium were published in a special issue of the *Cartography & Geographic Information Science* journal.

Drawing from discussions at the 2018 event, together with internal exchanges, UCGIS prepared a white paper titled *UCGIS Call to Action: Bringing the Geospatial Perspective to Data Science Degrees and Curricula* (https://www.ucgis.org/assets/docs/UCGIS-Statement-on-Data-Science-Summer2018.pdf) for the benefit of its member organizations and the broader geospatial community. As a long-established information science discipline, the geospatial sciences community can make key contributions to evolving data science curricula. With that in mind, the white paper (1) describes and clarifies the value of incorporating geospatial knowledge, skills, and data for students, employees, and employers within the emerging field of data science; (2) highlights potential pathways and opportunities for academic geospatial scientists to establish connections with other data science faculty on their university campuses; and (3) launches a national dialog about the synergistic benefits of mutually enriching data science and geospatial science curricula.

2019 UCGIS Annual Symposium

Under the direction of 2018–2019 president Alberto Giordano, the 2019 UCGIS Annual Symposium was held in Washington, DC, June 10–12. The symposium's theme was Geospatial Humanities: Towards a Transdisciplinary Approach. In recent years, there has been a renewed interest in a geographic perspective in the humanities. Broadly categorized, two approaches have emerged. The first, called the spatial humanities, has focused on GIS and GIScience as tools and methods of inquiry, with a quantitative perspective and an emphasis on representation. Historical GIS and geolinguistics are examples of spatial humanities projects. The second approach, called geohumanities, focuses on qualitative methods, cultural studies, and critical human geographies, with an emphasis on place. Literary cartographies are examples of geohumanities projects. The keynote presentations, panels, and paper sessions were designed to illustrate the interaction between the humanities and geography/GIScience with an eye toward the integration of space-based and place-based approaches. The proceedings of the symposium will be published as a double issue of the interdisciplinary journal *IJHAC—A Journal of the Digital Humanities* from Edinburgh University Press, with a scheduled publication date of March 2020.

The final day of the symposium, titled "Town Hall," was devoted to discussing matters related to the organization. The year 2019 marked the 25th anniversary of UCGIS and provided an incentive to reconsider what UCGIS can, should, and could be doing, and to start planning and designing a "UCGIS 2.0." During the upcoming year, several activities will be focused on updating the organization's strategic plan, mission, and activities, under the leadership of Karen Kemp, the 2019–2020 president of UCGIS.

The symposium was preceded by two workshops on Monday, June 10. One was a daylong workshop on the geospatial humanities, which introduced participants to the use of *corpus linguistics* and social network analysis as tools and methods to complement GIS and GIScience in the study of the humanities, with a case study from the Holocaust in Italy and Hungary. The other was a half-day workshop designed to reexamine the 1997 UCGIS education priorities (http://www.ncgia.ucsb.edu/other/ucgis/ed_priorities/contents.html). Participants discussed if the community has been successful in addressing the identified action items and whether each original priority was completed or needed to be updated. A new set of GIScience education challenges will be prepared in the upcoming year and will form the basis of some of the discussion to be held at the 2020 UCGIS Annual Symposium in Hawaii in June 2020.

TRELIS-GS

With funding from the NSF (grant #1660400), Training and Retaining Leaders in STEM—Geospatial Sciences (TRELIS-GS) (https://www.ucgis.org/trelis) is a three-year project aimed at providing professional development for women in higher education in the geospatial sciences and building leadership capacity and skills around the topics of career trajectories; mentoring and coaching; obstacles, conflicts, and solutions; communication and language; and work-life integration. The name *TRELIS* instills the concept of a human capital trellis, or scaffold of support, and embraces the reality of nonlinear career trajectories that move sideways, take leaps, and do not follow a single upward ladder. TRELIS-GS hosted workshops in conjunction with the 2018 and 2019 UCGIS symposia. A third is planned for the late spring of 2020. The TRELIS-GS leadership team includes faculty from the University of Maine, San Jose State University, Arizona State University, the University of Colorado, the University of Southern California, Tableau Software, and UCGIS.

Summer Schools on CyberGIS and Geospatial Data Science

Following the success of the 2017 Summer School on Collaborative Problem Solving with CyberGIS and Geospatial Data Science, in July 2019 a weeklong summer school on Reproducible Problem Solving with CyberGIS and Geospatial Data Science will be co-led by the CyberGIS Center at the University of Illinois at Urbana-Champaign (UIUC), the American Association of Geographers (AAG), and UCGIS. Approximately 30 graduate students and early career scholars will collaborate in developing novel solutions to complex problems as they take advantage of geospatial data science and cyberGIS. More information on the summer school can be found at https://cybergis.illinois.edu/event/aag-ucgis-summer-school-2019/.

Webinars

UCGIS hosts a series of webinars as a service to its members and to the larger GIScience community. The webinars offered between early 2018 and June 2019 include the topics listed below. Recordings of all webinars can be found at the UCGIS YouTube channel,

https://www.youtube.com/playlist?list=PLttHa2fWq22xw7vUhaVgxFTTXjnNSzeDY:

- "Reimagining the History of GIS," presented on February 27, 2018, by Michael Goodchild
- "FICUS: A Spatiotemporal Risk Analysis System & Black Swan Theory," presented on September 26, 2018, by Charles Ehlschlaeger (US Army Corps of Engineers)
- "Using Professional Credentialing Exams within Academic GIS Contexts," presented on December 11, 2018, by representatives from GISCI, ASPRS, and USGIF
- "Exploring Geo-Text Data: Place Names, Place Relations, and Place Sentiments," presented on January 29, 2019, by Yingjie Hu (University at Buffalo)

Future UCGIS Activities

In the 2019–20 year, UCGIS expects to focus on strategic planning to ensure that its activities, ideas, and capacity are aligned effectively.

U.S. Geological Survey Accomplishments in Cartography, 2015–2019

E. Lynn Usery

Senior Scientist, U.S. Geological Survey, usery@usgs.gov

Keywords: USGS, National Map, 3D Elevation Program, National Hydrography Dataset, US Topo

Abstract

The U.S. Geological Survey (USGS), the United States' official national topographic mapping organization, is building and maintaining geographic databases for fundamental base geographic layers of land cover, structures, boundaries, hydrography, geographic names, transportation, elevation, and orthoimagery as The National Map. Data from the 3D Elevation Program, the National Hydrography Dataset and other national programs provide public domain, authoritative, accurate, and reliable data for The National Map, and data are served to United States government organizations and the public. Products of The National Map include viewable and downloadable data for all data layers, derivative products including US Topo, and web services of the data. The US Topo product is automatically generated from national map databases and produces topographic maps every three years for all 48 of the contiguous United States, Hawaii, and the United States territories.

Introduction

The U.S. Geological Survey (USGS) is the official national mapping organization for United States topographic mapping. Since 2009, United States topographic mapping in digital form, created and managed by the National Geospatial Program (NGP) of the USGS, has been generating digital topographic maps such as US Topo[1] from the databases of The National Map.[2] US Topo is a digital version of the USGS traditional topographic map in 7.5-minute quadrangles rendered at a scale of 1:24,000. The NGP began development of an automated map production system based on geographic information system technology in 2008 to produce the US Topo product. That system has continually been refined, and more content is added to the US Topo product each year. The program provides complete coverage of the United States, except for Alaska, every three years. Thus, from 2016 to 2019, the NGP completed the third complete cycle of coverage for the United States with these maps. Also, during this period, US Topo coverage for Alaska achieved 85 percent completion, with 100 percent completion of Interferometric Synthetic Aperture Radar coverage at 5-meter resolution for Alaska.

US Topo is a derivative product from The National Map, which includes eight data layers: land cover, structures, boundaries, hydrography, geographic names, transportation, elevation, and orthoimagery. The US Topo product currently includes geographic features from each of these layers. The features on US Topo are structured as a Geospatial PDF and allow a user to turn on layers as desired for a rendered visual product. Each data layer is being continually updated. In the last four years, lidar data have been used to generate elevations at one-meter post spacing with a vertical accuracy of 9.25 cm root mean square error, and currently, in 2019, more than 50 percent of the conterminous United States, Hawaii, and the Unites States territories have been completed. Additionally, the NGP has begun developing hydrography data as National Hydrography Dataset High Resolution Plus[3] (NHDPlus HR), which includes 1:24,000-scale or better resolution hydrography, plus elevation-derived attributes, such as flow direction and flow accumulation matrixes, stored within the NHD Plus HR data model. As of 2019, 75 percent of NHDPlus HR Beta data have been generated and made available as part of The National Map.

US Topo

Content that was added to US Topo during the last four years includes data for the U.S. Bureau of Land Management (BLM) Public Land Survey System, the U.S. Fish and Wildlife Service (FWS) National Wetlands Inventory, U.S. National Scenic Trails, commercial roads, wetlands, campgrounds, landforms, visitor centers, ranger stations, wild and scenic rivers, and trailheads. Bar codes were added to each map to facilitate ordering and printing. Also, in the last four years, the USGS completed the second and third cycles of coverage of US Topo for the conterminous United States.

The US Topo production system was transitioned to a cloud-based paradigm for map generation in June 2017. The transition included a new Python-based workflow and a map format change from GeoPDF to Geospatial PDF. The system currently supports US Topo production activities to generate 18,000 maps per year, with a peak capacity output of 30 maps per hour.

The USGS maintains and updates five multiscale raster cache basemaps and 37 web services in a reliable cloud-based environment. These National Map basemaps and services have undergone several cartographic design changes to improve readability and contrast. The set of basemaps include USGS Topo, USGS Imagery Topo, USGS Imagery Only, USGS Shaded Relief, and USGS Hydro NHD.

Elevation Data

The 3D Elevation Program (3DEP) was initially envisioned in the 2014 USGS publication *The 3D Elevation Program Initiative—A Call for Action* (Sugarbaker et al. 2014).[4] A nationwide lidar program seemed an impossible dream due to the estimated cost of $1 billion and the unprecedented data management challenge that would result. However, rapidly growing data demand; industry efficiency and cost improvements; and documented annual program benefits, estimated to reach $13 billion, convinced the USGS to undertake the goal of nationwide data coverage in eight years. Production of 3DEP began in 2016 with the target to complete data acquisition in 2023. Data acquisition partnerships and funding have been growing every year. By the end of fiscal year 2018, data that meets the 3DEP specification were available or in progress for over 50 percent of the nation. This milestone[5] is truly a community achievement, including the partners that fund acquisition, the vibrant lidar industry and private sector mapping firms that collect the data, and a growing and innovative user base.

The 3DEP data are processed by the USGS, using both commercial and open-source software. Processing currently occurs using on-premises hardware in a Windows-based environment. There are currently over two million lidar point cloud tiles (averaging about 56 Mb in size for each tile) available for download. Data are served for free via File Transfer Protocol (FTP) or Amazon Web Services S3 user-pay bucket. The program has provided data delivery and 3D visualization via the cloud through both free download and premium, user-paid services to support very large volume access and in-cloud processing. The lidar point clouds have been processed with Entwine and made available in Entwine Point Tile format as an Amazon Web Services open data public offering. The digital elevation model (DEM) products are now derived from the lidar source and are also a very popular 3DEP product. A recently added dynamic elevation service renders shaded relief, slope, aspect, and contours, using on-the-fly processing of DEMs derived from high-resolution lidar data.

Hydrography Data

The National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)[6] form a rich data suite that map surface-water network and hydrologic unit areas of the United States. To link the stream network to the landscape and calculate important attributes such as stream order and estimated streamflow, the USGS is now developing the nationwide NHDPlus HR framework, an integrated hydrography and elevation data suite that includes the NHD stream network, polygonal catchment drainage areas, flow direction and flow accumulation raster matrixes, and value-added attributes. The NHDPlus HR, which includes contributing areas and hydrography in Canada and Mexico, is built using the NHD at 1:24,000-scale or better, 1/3 arc-second seamless 3DEP data, and a nationally complete WBD. The NHDPlus HR is being built in an iterative fashion. As of 2019, a first beta version of NHDPlus HR has been developed for approximately three-quarters of the nation, including most of the conterminous Umited States and limited areas of Alaska. The USGS regularly collects corrections to the NHD, WBD, and NHDPlus HR datasets using a web-based markup application.

The NHD is a multiscale dataset containing a national baseline of 1:24,000-scale data. Local partners have replaced the feature data with better scales to meet their needs. In order to use the multiscale NHD dataset to create a consistent 1:24,000 layer for the US Topo product, NGTOC developed a method to apply generalization on the fly in the last four years. A visibility filter for generalization is 90 percent populated in the conterminous United States in the NHD dataset. The filter allows users to represent NHD vector features at eight different map scales. Although NHD is compiled from multiple scales of source data, the visibility filter allows users to display or use these data at a range of scales that support local or regional analysis. Visibility values are determined through a stratified pruning process that relies on a natural drainage density pattern derived through a weighted flow accumulation model, the result of original research at USGS.

Transportation Data

The National Transportation Dataset (NTD) layers contain roads (including tunnels and ferry routes), railroads, airports and runways, and trails. These datasets were created and are maintained by integrating USGS partner data into the NTD. USGS partners include the U.S. Census Bureau; the U.S. Forest Service; the U.S. National Park Service; the Federal Aviation Administration; the Federal Railroad Administration; the FWS; the BLM; and state, local, and private companies.

Structures Data

The National Map Corps[7] (TNMCorps) is an online crowdsourcing mapping project with volunteers successfully editing structures in all 50 Unites States, Puerto Rico, and the Unites States Virgin Islands. Within The National Map, structures include schools, hospitals, post offices, police stations, cemeteries, and other important public buildings. Since 2012, volunteers have made more than 500,000 edits to over 400,000 structure points, representing roughly 82,000 volunteer hours and being equivalent to the work of nearly 40 full-time employees. By updating and verifying structures data, volunteers are making significant contributions to the USGS National Structures Database; The National Map; and, ultimately, US Topo.

Conclusion

The USGS is advancing topographic mapping with geographic information system technology and providing geospatial databases from The National Map to serve United States scientists, administrators, and the public at large. Geospatial data and maps are of high resolution, publicly available, and freely downloadable. The USGS continues to provide the latest in mapping technology to serve data products to the United States and the world.

References

[1]"National Geospatial Program—US Topo: Maps for America," U.S. Geological Survey, accessed June 4, 2019, https://www.usgs.gov/core-science-systems/national-geospatial-program/us-topo-maps-america?qt-science_support_page_related_con=0#qt-science_support_page_related_con.

[2]"National Geospatial Program—The National Map," U.S. Geological Survey, accessed June 4, 2019, https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map.

[3]"National Hydrography Dataset High Resolution Plus," U.S. Geological Survey, accessed June 11, 2019, https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution.

[4]*The 3D Elevation Program Initiative—A Call for Action*, Circular 1399, U.S. Geological Survey, accessed June 4, 2019. Sugarbaker, L. J., E.W. Constance, H. K. Heidemann, A. L. Jason, V. Lukas, D. L. Saghy, and J. M. Stoker, 2014. https://doi.org/10.3133/cir1399.

[5]"3D Elevation Program—3DEP Data Acquisition Status Maps," United States Geological Survey, accessed June 4, 2019, https://www.usgs.gov/core-science-systems/ngp/3dep/3dep-data-acquisition-status-maps.

[6]"National Hydrography—Watershed Boundary Dataset," U.S. Geological Survey, accessed June 4, 2019, https://www.usgs.gov/core-science-systems/ngp/national-hydrography/watershed-boundary-dataset?qt-science_support_page_related_con=4#qt-science_support_page_related_con.

[7]"The National Map Corps," U.S. Geological Survey, accessed June 4, 2019, https://www.usgs.gov/core-science-systems/ngp/tnm-corps.

National Charting Plan Implementation

Christie L. Ence *, John E. Nyberg, Dr. Shachak Pe'eri

NOAA Office of Coast Survey, Marine Chart Division, Christie L. Ence, Christie.Ence@noaa.gov, John E. Nyberg, John.Nyberg@noaa.gov, Shackak Pe'eri, Shachak.Peeri@noaa.gov

* Corresponding author

Keywords: Cartography, Maritime Products, Nautical Charts

Abstract

In an effort to evolve its nautical chart products to suit the modern maritime customer's needs, the National Oceanic and Atmospheric Administration (NOAA) developed the National Charting Plan. The proposal included strategies to address known issues with NOAA's nautical chart suite, focusing on improving chart coverage, addressing encoding issues within chart products, and reducing redundancy in distributed information.

Introduction

In November 2017, the National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey (OCS), Marine Chart Division (MCD), released its National Charting Plan, which outlines ways "to improve NOAA nautical chart coverage, products, and distribution" (NOAA 2017a). The plan's ultimate goal is to provide the user easier access to higher quality, timelier chart information. To meet this goal, MCD staff assembled the Chart Transformation Team to address the issues defined in the plan. After some discussion, the team of cartographers dissected the National Charting Plan into 14 chart transformation tasks (table 1), five of which are discussed in this article.

Table 1. National Charting Plan Chart Transformation Tasks. Tasks highlighted in bold are discussed in further detail in this paper.

National Charting Plan Chart Transformation Tasks
• **Electronic Navigational Chart (ENC) rescheming**
• Replacement of channel survey depths with project depths on paper and raster charts
• ENC application of US Army Corps of Engineers eHydro data
• Development of policy for compilation of hydrography within channels on ENCs
• MCD-wide use of US Coast Guard aids to navigation data in XML format
• **Resolution of charted uncertainties (reported dangers)**
• Reduction of electronic chart display and information system (ECDIS) alarms resulting from null depth attribution
• **Compilation of integer meter ENC depth contours**
• Small-craft chart coverage migration to standard-style products

- Preparation for and provision of the first session of S-8 CAT-B Certification Program in MCD
- **Encoded category of zone of confidence (CATZOC) for all surveys in all ENCs**
- Encoded magnetic variation features in all ENCs for corresponding compass roses
- MCD acquisition of responsibility for compiling hydrographic surveys
- Raster Navigational Chart (RNC) rescheming

Improving Chart Coverage

Currently, NOAA's electronic charts reflect the unique nature of their original paper chart sources. They display chart data at 131 distinct scales using irregularly shaped cell extents. NOAA is in the process of rescheming its electronic chart suite to increase efficiency and ease of use for the mariner. The reschemed charts follow a regular gridded pattern; maintain consistent sizes and shapes; and display chart information on 12 binary scales, in which each scale is half the size of the previous scale (1:10,000, 1:20,000, 1:40,000, etc.). The new scheme will assign cell numbers using either the US state or port designation with an alphabetical sequence indicating the location of the cell in the local grid.

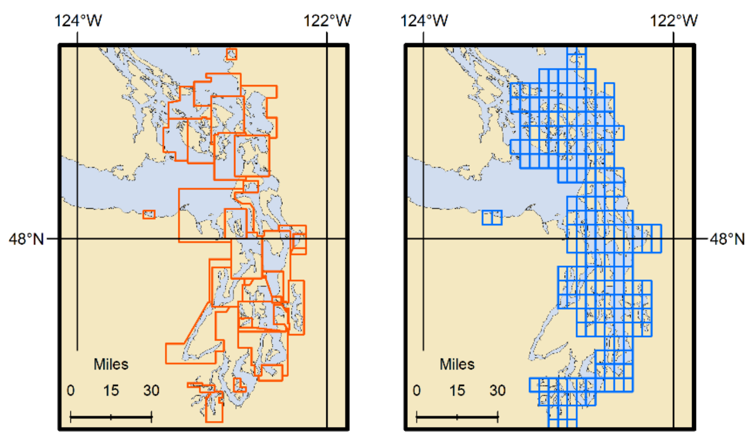


Figure 1. Current large-scale NOAA ENC coverage in Puget Sound, Washington (left). Reschemed large-scale NOAA ENC coverage in Puget Sound, Washington (right).

Improving Chart Products

As noted above, NOAA's ENCs were traced from their corresponding paper charts. However, some charting practices suitable for individual paper charts—such as imperial depth contour intervals, positional and depth uncertainties of dangers to navigation, and incomplete data quality attribution—become problematic for digital charts. Each of these is explained in more detail below.

Most paper charts provided depth information in either fathoms or feet. These imperial units must be converted to decimal metric values to meet international standards. However, this results in unusual contour values that are difficult to interpret. It can also pose a problem for mariners who use an ECDIS. The National Charting Plan (NOAA, 2017b) cites the following example: many medium-scale NOAA charts depict the 30- and 60-foot contours, which translate to 9.1 meters and 18.2 meters, respectively. If the mariner set the safety contour to 10 meters, which is common practice, the ECDIS would default to the 18.2-meter contour, since the 10-meter contour is not charted. This could drastically limit the navigable water available to the mariner, depending on the slope of the seabed. As part of NOAA's rescheming project, the most up-to-date survey for all areas will be recompiled using an automated tool. This tool will generate new depth contours in whole-meter intervals to align all reschemed products with international standards.

It is NOAA's responsibility to chart reported dangers to navigation, including rocks, wrecks, and obstructions. Sometimes, the position or depth of the reported danger is uncertain. Regardless, the hazard is charted, with an uncertainty indicator included. As modern hydrographic surveys are conducted, some of these reported dangers can be confirmed or disproved. However, many more reported dangers are not yet resolved. Additional resources are being deployed to investigate these remaining uncertain dangers, prioritizing high-traffic areas (NOAA, 2017b).

Finally, the original paper chart products display survey-quality information in source diagrams. However, there is no direct conversion between the paper chart source diagram, which classifies hydrographic data by time period, to the internationally recognized CATZOC used on ENCs. Because of this, many ENCs have encoded waterways, including maintained channels, as "unassessed" or "U." Unfortunately, this U categorization is often misinterpreted as standing for "unsurveyed," which would be of concern to mariners. To address this, NOAA has undertaken the task of reassessing historic hydrographic surveys using the international CATZOC method of classification. Once surveys for a region were reevaluated, the affected ENCs were updated with the correct CATZOC encoding.

Improving Chart Distribution

The means for disseminating chart products have evolved over time. Historically, NOAA employed in-house lithographic printing presses to publish paper nautical charts sold by certified agents. In 2014, NOAA discontinued printing lithographic charts and started providing print-ready files online for vendors to print and distribute, themselves. ENCs are available for download on the NOAA Office of Coast Survey website or through a value-added reseller (VAR).

In addition to improving the way charts are provided to the user, NOAA aims to reduce redundancy of the information provided. For example, both NOAA paper and digital charts traditionally have provided mariners with maintained channel depths. However, that information is already published on the US Army Corps of Engineers (USACE) website. From now on, NOAA will not publish channel depths on paper charts, though the information will still be available on ENCs. By doing this, NOAA reduces the likelihood of discrepancies and gains source application efficiency.

Conclusion

As can be seen, NOAA is striving to meet current and anticipated future needs of the user. The objective is to eliminate redundancies and unnecessary warnings, which erode user confidence, and to increase display and interpretation efficiency and keep abreast with advancing technology to ensure that NOAA navigational chart products provide the best information available.

References

"NOAA Releases Final National Charting Plan," Office of Coast Survey. November 15, 2017a, https://nauticalcharts.noaa.gov/news/final-national-charting-plan.html.

"National Charting Plan—A Strategy to Transform Nautical Charting," Office of Coast Survey, Marine Charting Division, November 1, 2017b, https://nauticalcharts.noaa.gov/publications/docs/national-charting-plan.pdf.

Recent Cartographic Activities at the Smithsonian Institution

Daniel G. Cole

Smithsonian Institution, IT Office, MRC 136, Washington, DC 20013-7012, coled@si.edu

Keywords: Smithsonian, Museums, Maps, GIS, Exhibits

Abstract

Mapping and geographic information system (GIS) applications in the museum environment provide the opportunity to educate the public on a variety of themes (oceanography, biogeography, paleobiology, physical geography and geology, environment, history, human origins, and ancient cultures). Museum exhibits provide maps in several different formats, from generalized maps from which visitors can glean spatial information to detailed maps that require visitors to stop and study so that more can be learned to interactive maps, story maps, and GIS applications. Maps and GIS help museum visitors navigate, and cartographic displays provide geographic context to collections and photographs within the exhibit. At the same time, they can also be abstractions. Thus, museum maps must be designed not to be distractions to the main exhibit; rather, they must add to and enhance the learning experience for museum visitors.

Introduction

The Smithsonian Institution is an international research and educational institution, home to 19 museums, the National Zoological Park, and 9 research centers. It is dedicated to the "increase and diffusion of knowledge" centered on its collections of 154 million artifacts, art, and specimens. Exhibits at the Smithsonian museums often include maps that were created by Dan Cole (the Smithsonian cartographer), staff artists, or outside contractors. Collaboration on the conceptual development and production of the maps typically occurs between the cartographer, curators and their colleagues, exhibit staff, and set designers.

During the past four years, a number of temporary exhibits at the Smithsonian Institution have opened that included static printed maps and interactive digital maps to provide geographic education on specific topics for visitors. The remainder of this article details maps that have appeared in exhibits at the Smithsonian over the past four years.

National Museum of the American Indian

In July 2015, the National Museum of the American Indian (NMAI) opened an exhibit (7/2015–6/2020) titled *Qhapaq Ñan—The Great Inka Road: Engineering an Empire*. This exhibit includes maps of the following topics: the Inka Road network (over 40,000 km) (fig. 1); the preceding cultures (Chavín, Tiwanaku, Wari, and Chimú); the expansion of the Inka empire (which the Inka called Tawantinsuyu); the four regions of the empire (Chinchaysuyu, Antisuyu, Collasuyu, and Contisuyu); the Spanish invasion; the positioning of the Pan-American highway over much of the network's coastal route; a Google Earth fly-through from Cusco to Machu Picchu; an interactive 3D map table of Cusco as it existed in 1531; and an interactive game dealing with the primary function of the network—communication via human "pony express." The website for this exhibit is https://americanindian.si.edu/inkaroad/.

Figure 1. The Inka Empire (Tawantinsuyu) and the Inka Road network **(**Qhapaq Ñan).

National Museum of Natural History

In August 2017, the National Museum of Natural History (NMNH) opened an exhibit (8/2017–9/2019) titled *Narwhal: Revealing an Arctic Legend* with five static maps illustrating the physical oceanscape with the narwhal's distribution (fig. 2), human settlements, and industrial activities in the Arctic, as well as an animated map of the Annual Arctic Sea Ice Minimum, 1979–2016, by Cindy Starr of the National Aeronautics and Space Administration (NASA) (https://svs.gsfc.nasa.gov/4573). Through firsthand accounts from scientists and Inuit community members, the exhibition reveals how traditional knowledge and experience, coupled with the latest scientific research, heighten our understanding of these fascinating animals and our changing global climate.

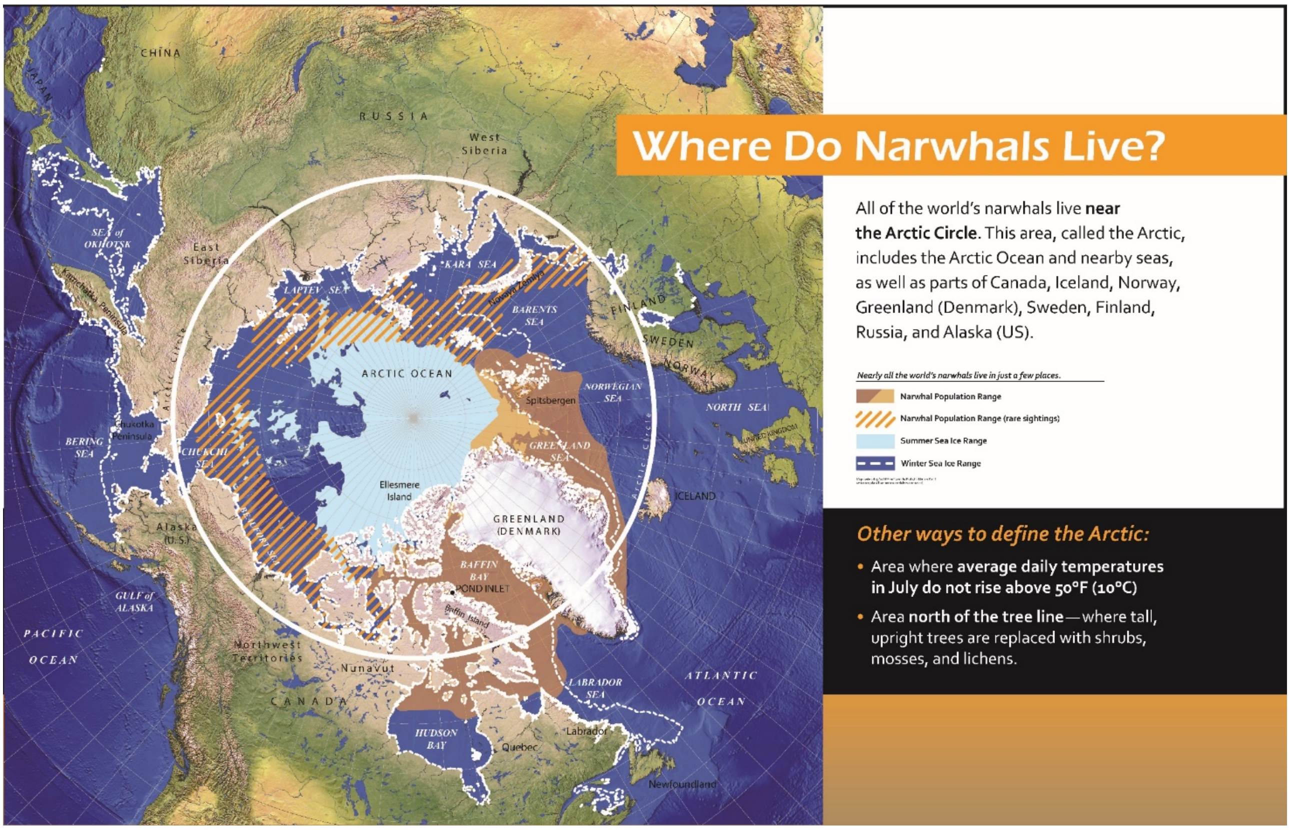


Figure 2. The Arctic distribution of narwhals (browns), with the minimum ice pack of 2016 (cyan) and the maximum sea ice extent (dashed white line).

May 2018 (until 2021) saw the opening of an exhibit at NMNH titled *Outbreak: Epidemics in a Connected World*. *Outbreak* invites visitors to join epidemiologists, veterinarians, public health workers, and citizens of all ages and origins as they rush to identify and contain infectious disease outbreaks. Case studies of HIV/AIDS, Ebola virus, and influenza highlight the social and emotional fallout of outbreaks—for victims, their loved ones, and society overall. This exhibit has an interactive map kiosk with daily updates from ProMED's Healthmap (https://www.healthmap.org/promed/). Additionally, a joint project by NMNH's Entomology Department and the Walter Reed Biosystematics Unit has an interactive map website VectorMap (fig. 3) (http://vectormap.si.edu/). VectorMap provides disease maps, mapped collection data, and distribution models for arthropod disease vector species, including mosquitoes, ticks, sand flies, mites, and fleas, as well as the hosts/reservoirs of vector-borne disease pathogens. Collection records are searchable and downloadable, and users can map and contribute their own georeferenced collection data or distribution models. All contributions have full attributions.

Sackler Asian Art Gallery

During October 2017, the Sackler opened an exhibit (10/2017–11/2020) titled *Encountering the Buddha: Art and Practice Across Asia* with a 9-foot-wide map (fig. 4) and interactive kiosk showing southern and eastern Asia with the locations where Hyecho, a Korean Buddhist monk, travelled for three years. The kiosk shows photos of the places that Hyecho visited and artifacts that he encountered along the way. Visitors to *Encountering the Buddha* can step into a reconstructed Tibetan Buddhist shrine, linger at a Sri Lankan stupa, travel with an eighth century Korean monk, and discover remarkable objects. The exhibition draws upon the museum's collections of Buddhist art from Afghanistan, India, Southeast Asia, China, and Japan. By exploring new narratives and technologies, *Encountering the Buddha* invites visitors to reconsider Buddhist practices and concepts of beauty.

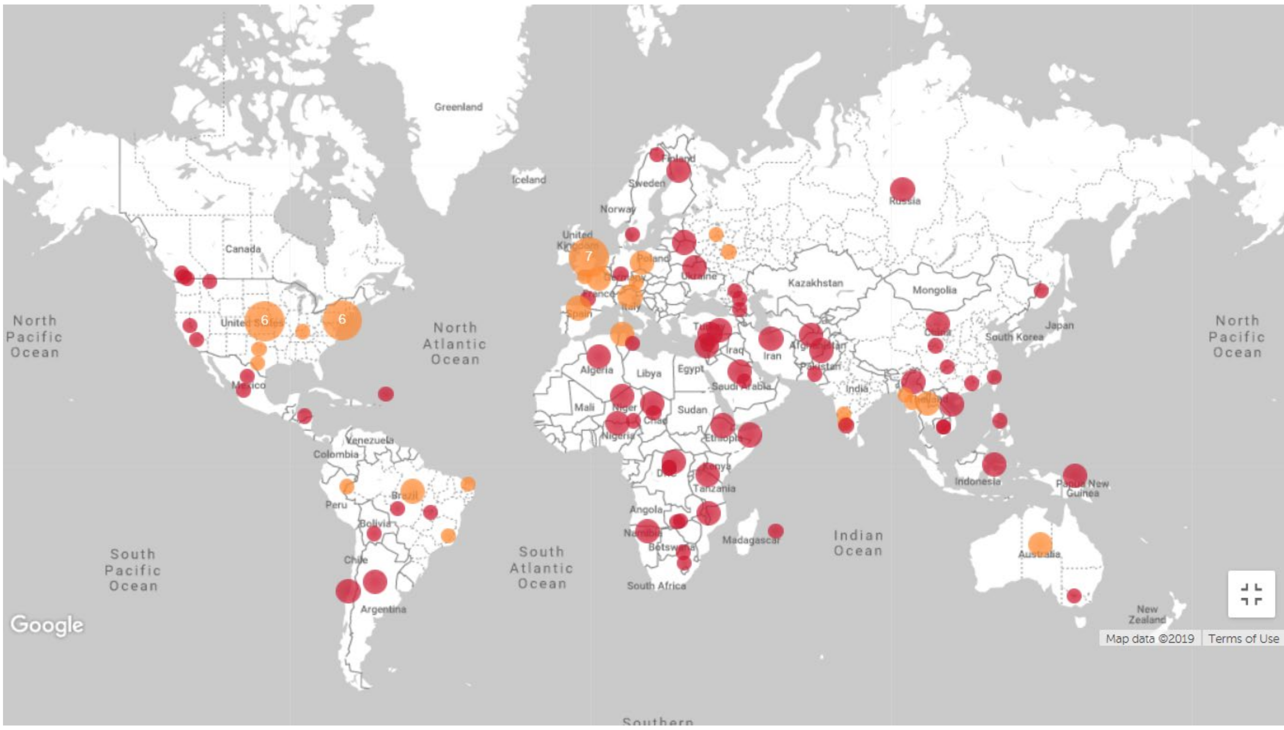


Figure 3. ProMED's HealthMap (https://www.healthmap.org/promed/).

Figure 4. Large map of southern and eastern Asia illustrating the locations that Hyecho visited.

National Museum of American History

In May 2019, the National Museum of American History (NMAH) opened an exhibit celebrating the 150th anniversary of the transcontinental railroad that focuses in part on the forgotten workers, Chinese migrants, who built the western leg of the railroad across the Sierra Nevada Mountains. A display describes how the railroad was a catalyst for positive change but displaced Native Americans and caused the near extinction of the American buffalo. The physical exhibit included a 16-foot floor map from 1868 by the General Land Office that shows the existing rail network plus several proposed routes of the transcontinental railroad, along with surveys and the locations of deposits of nine different minerals. The online version of the map illustrates the country as it existed at the completion of the transcontinental railroad (fig. 5), including the physical background, the rail network, states and territories, Indian reservations, and navigable rivers and canals. Two additional maps of the western US show historic trails and American Indian nations at contact. The exhibit will remain open until May 2020.

Figure 5. The transcontinental railroad and the state of the country in 1869.

Smithsonian Folklife Festival

The annual Smithsonian Folklife Festival hosts visual and performing arts from around the world, which, in the past few years, have included performers and cultures from Peru, the Spanish and French Basque, Armenia (fig. 6), and Catalonia. Maps for this event are designed and distributed to give visitors information about the locations of the artists' villages as well as their surrounding cultural and physical terrains.

Figure 6. Physical map of Armenia illustrating the home sites of the performing artists.

Conclusion

Overall, maps and GIS provide geographic education to the public associated with biological, geological, and cultural presentations. With these geospatial tools, the public gains geographic knowledge of the nation's history and environment. Visitors may also relate where collections were found and where they might be found in the future based on changing environmental conditions. Earth has dynamic physical, biological, and cultural environments that are best presented to the public in museums like the Smithsonian due to the wealth of artifacts and specimens that are mapped and displayed.

Cartography at the University of Wisconsin−Madison

Tanya Buckingham, Jaime Martindale, and Robert Roth *

Department of Geography, University of Wisconsin−Madison, Tanya Buckingham, tanya.buckingham@wisc.edu, Jaime Martindale, jmartindale@wisc.edu, Robert Roth, reroth@wisc.edu

* Corresponding author

Keywords: Cartography, Cartography curriculum, Map library, Map production, Design challenge

Abstract

The Geography Department of the University of Wisconsin at Madison (UW−Madison) offers a diverse array of programs, courses, workshops, and services in cartography. In this article, we highlight the major updates of the past four years to the UW−Madison cartography programs and curriculum. We also describe selected new projects from two of the UW−Madison cartography units: the Robinson Map Library and the University of Wisconsin Cartography Lab.

Introduction

Founded in 1928, the University of Wisconsin at Madison Geography Department has offered courses on cartography since 1937. Cartography curriculum and activities expanded rapidly after professor Arthur Robinson joined the UW−Madison Geography Department faculty following World War II. Today, the cartography curriculum sits within a campus-wide array of courses and programs covering geospatial data, geographic information system (GIS) technology, remote sensing, and spatial statistics. Further, the Geography Department houses several permanently staffed units that support campus- and statewide cartography initiatives, including the University of Wisconsin Cartography Lab, the Geospatial Data Science Lab, the History of Cartography Project, the Robinson Map Library, and the State Cartographer's Office. In this article, we highlight major updates of the past four years to the cartography programs and curriculum at UW−Madison and describe selected new projects from two of the cartography units: the Robinson Map Library and the University of Wisconsin Cartography Lab.

Cartography Programs at UW−Madison

Cartography is a foundational competency for all UW−Madison Geography programs, including separate undergraduate majors and master of science (MSc) degrees in both the geography and the cartography and GIS programs. In 2015, the Geography Department launched a new, professional online MSc degree in GIS and web map programming, which has since diversified into a suite of four professional-oriented, blended-learning programs (for more information, see https://geography.wisc.edu/gis/). Altogether, the UW−Madison Geography Department currently offers eight programs requiring cartography:

- Undergraduate major in geography—Students select an intermediate course in cartography or GIS as a breadth requirement.
- Undergraduate major in cartography and GIS—Students complete one intermediate course in cartography and select one or two advanced cartography electives.
- One-year postbaccalaureate GIS fundamentals certificate—Students complete one intermediate course in cartography.
- One-year postbaccalaureate advanced GIS certificate—Students select one or two advanced courses in cartography.
- Thesis master's degree in cartography and GIS—Students complete one intermediate course in cartography, one graduate seminar in cartography or GIS, and one or two advanced cartography electives.
- Accelerated master's in cartography and GIS—Students complete one intermediate course in cartography and select one or two advanced cartography electives.
- Online master's in GIS and web map programming—Students complete two advanced courses in cartography.
- PhD in geography—Students complete two graduate seminars in cartography, GIScience, or geography, and may complete additional coursework in cartography based on the dissertation focus and background deficiencies.

Cartography Curriculum at UW−Madison

UW−Madison Geography offers five courses fully or partially dedicated to cartography instruction to support its programs. Curriculum is organized by a pair of orthogonal axes capturing the range of competencies defining contemporary cartography: map use versus mapmaking and representation design versus interaction design (fig. 1).

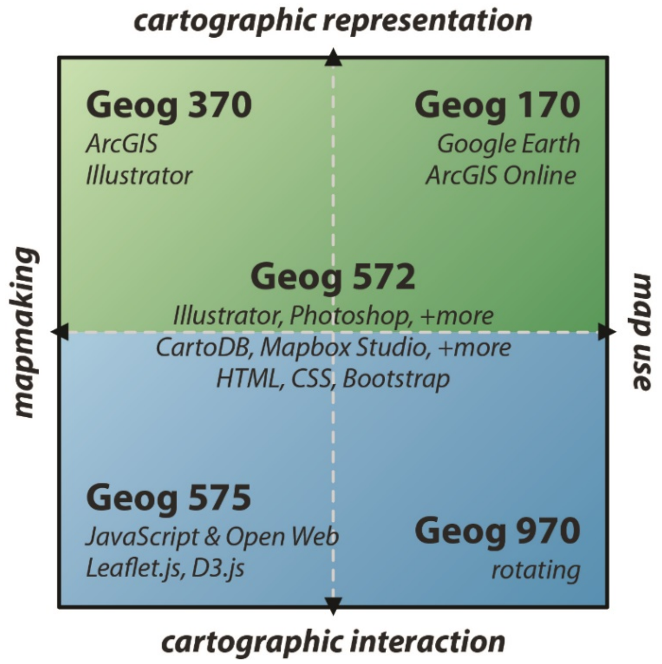


Figure 1. Cartography Curriculum at UW−Madison. Cartography courses are organized to consider map use versus mapmaking and representation design versus interaction design. Each UW−Madison program requires its own sequence through the courses and associated technical competencies. Figure used with permission from Roth (2016).

UW−Madison cartography courses include the following:

- Geography 170 (G170), Our Digital Globe (map use plus representation design), a three-credit introductory survey of map use and geospatial technologies—Lessons introduce the use of geospatial data, GPS, remote sensing, and GIS to address our planet's most pressing problems. This course closes with a three-week module on cartography. G170 is offered completely online and enrolls 200 students per semester.
- Geography 370 (G370), Introduction to Cartography (mapmaking plus representation design), a four-credit intermediate course covering cartographic design concepts, best practices, and success stories—Lessons are divided between reference and thematic mapping, with copious in-class map examples for discussion to help students develop a critical eye for cartographic design. G370 includes equal lecture and lab components, with lab assignments framed as real-world client scenarios to promote active learning. This course enrolls 80 students per semester.
- Geography 572 (G572), Graphic Design in Cartography (integration of competencies), a four-credit advanced course on cartographic design and visual storytelling—Lessons help students develop a critical understanding of how maps work from the perspectives of visual perception, visual cognition, and visual culture. G572 includes equal lecture and lab components, with each lab assignment integrating workflows across from three to four different geospatial technologies. This course enrolls 40 students per semester.
- Geography 575 (G575), Interactive Cartography & Geovisualization (mapmaking plus interaction design), a four-credit, programming-intensive course on interactive, online, and mobile mapping—Lessons discuss map user experience (UX) and user interface (UI) design considerations faced in cartography. G575 includes equal lecture and lab components, with collaborative lab assignments supported by GitHub. This course enrolls 40 students per semester.
- Geography 970 (G970), Seminar in Cartography (map use plus interaction design), a three-credit graduate seminar addressing emerging mapping problems and map use contexts—Past topics have included mobile map design and user studies in cartography. G970 comprises article discussion and map critiques. This course enrolls 12 students per semester.

Learning objectives for G370, G572, and G575 were updated in 2018 to align with Bloom's revised taxonomy, using feedback from University of Wisconsin Cartography Lab and Robinson Map Library staff and students (table 1).

Table 1. Revised learning objectives for UW−Madison cartography courses

Geography 370: Introduction to Cartography	*Geography 572: Graphic Design in Cartography*	*Geography 575: Interactive Cartography & Geovisualization*
Design maps. Topics include • Map projections and the geographic coordinate system. • Map generalization across map scales. • Map typography and the design and placement of text on maps. • Visual hierarchy and map layout. • Map symbolization and design considerations for thematic maps. • Statistical mapping, including levels of measurement, enumeration, normalization, and classification.	Explain how maps work, including • How maps work as a narrative form. • How visual attention is directed through map symbolization and the visual variables. • How visual form is constructed in maps through contrast, grouping, and figure-ground. • How visual complexity influences the way maps are understood. • How sign systems, like maps, are mediated. • How maps function as art. • How maps exercise power and marginalize the disempowered.	Design interactive maps. Topics include • User experience (UX) and user interface (UI) design. • Interface complexity, constraint, flexibility, and freedom. • User- and technology-based constraints on UI/UX design. • Interaction operators (e.g., pan, zoom, search, filter) and web map UI solutions. • Nonmap visualization techniques. • Direct and indirect map-based interface styles. • Coordinated big data visualization and interactive highlighting techniques.
Produce maps: • Execute original map designs from conceptualization to delivery. • Estimate and manage the time needed for an open-ended design project. • Design within client-defined constraints. • Acquire and prepare geographic datasets. • Follow and deviate from a cartographic workflow using ArcGIS and Illustrator.	Design maps. Topics include • Visual storytelling genres and tropes. • Bivariate and multivariate mapping. • Visual layout and balance. • Terrain representation. • Representation of time. • Iconic map symbol design. • Aesthetics and style.	Develop interactive maps: • Follow and deviate from a cartographic workflow using HTML, CSS, and JavaScript. • Construct spatiotemporal and multivariate visualizations using Leaflet.js and D3.js. • Think computationally to consult web resources and debug source code. • Deploy web maps on the Open Web Platform using GitHub code repositories.
Critique maps: • Consider cartographic design within its broader historical and social contexts. • Deconstruct maps by their elementary design components to identify opportunities and alternatives. • Provide constructive feedback for peers during the process of design. • Self-critique and edit personal designs using professional standards.	Produce maps: • Execute original map designs from conceptualization to delivery. • Design within client-defined constraints. • Acquire and prepare geographic datasets. • Follow and deviate from four different workflows using the ArcGIS platform, the Adobe Creative Suite, Mapbox Studio, and the Bootstrap framework. • Optimize maps for the web. • Publish a professional web portfolio.	Produce interactive maps: • Plan and execute a user-centered design process, from needs assessment to transition. • Acquire and prepare geographic datasets. • Design within user-defined and technology-defined functional constraints. • Evaluate and improve prototypes and application releases. • Work in small groups using GitHub versioning and collaboration tools.
	Critique maps. • Consider cartographic design within its broader historical and social contexts. • Deconstruct maps by their elementary design components to identify opportunities and alternatives. • Provide constructive feedback for peers during the process of design. • Self-critique and edit personal designs using professional standards and ethical guidelines. • Present personal work to colleagues.	

The Robinson Map Library

Established in 1945, the Robinson Map Library (RML) at the University of Wisconsin−Madison Department of Geography comprises cartographic research collected from around the world (for more information, see: https://geography.wisc.edu/maplibrary/). The library supports research and teaching in cartography and GIScience, attracting users ranging from university researchers and students to the general public. The print collection, valuable for its historic content, contains over 300,000 maps and 250,000 historic aerial photos.

In addition to maintaining a relevant print collection, the library plays a significant role in geospatial data archiving, data curation, and long-term map preservation. With an initial focus on Wisconsin data, the library archive has grown to include both licensed and academic research data. An example of this work is the library's role in the Big Ten Academic Alliance (BTAA) geoportal project (fig. 2). The BTAA geoportal aggregates geospatial data, metadata, and scanned maps from 11 partner institutions into a single online resource, enhancing the user experience in terms of discovery and access. It is an important collaborative project in which new tools and best practices have been implemented to improve the way users search for and acquire geospatial content online. The RML has played a particularly significant role in advancing metadata standards, creating sustainable content management workflows, and authoring help guides to share with the broader geospatial library community.

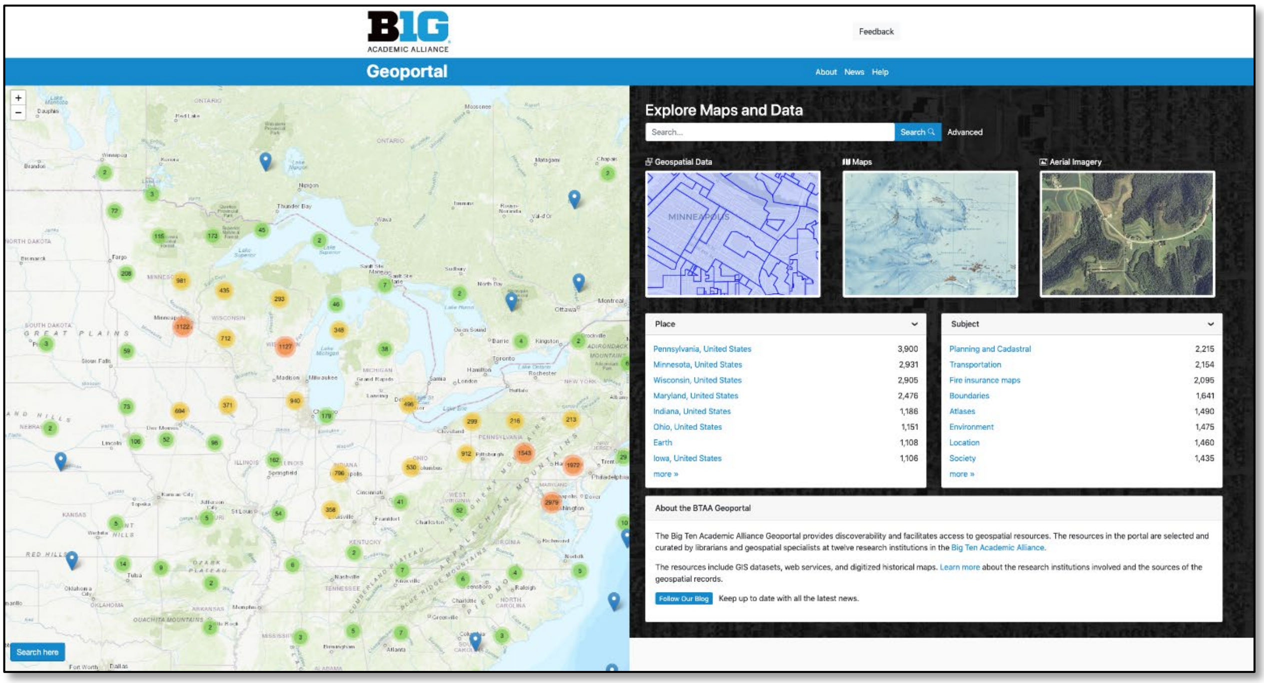


Figure 2. The Big Ten Academic Alliance Geoportal. The geoportal is available at https://geo.btaa.org/.

The University of Wisconsin Cartography Lab

Established in 1953, the University of Wisconsin Cartography Lab (Cart Lab) is a full-service production facility that conducts research and development on cartographic design and geographic visualization (for more information, see: https://geography.wisc.edu/cartography/). The Cart Lab works with partners across the University of Wisconsin system, including municipal and federal government agencies and commercial clients and publishers. The Cart Lab regularly employs from 15 to 20 student cartographers, providing both undergraduate and graduate students with a unique apprenticeship experience on research and design projects.

Recent projects include four National Science Foundation grants: one dedicated to basic science research on interactive cartography, and the others on collaborative, transdisciplinary projects intersecting human and physical geography. In the past three years, the Cart Lab also has designed the maps and illustrations for geography textbooks (in physical geography, human geography, and cartography, respectively) and popular audience books, such as *Connectography: Mapping the Future of Global Civilization*. The Cart Lab also regularly works with academic and trade journals, with recent credits including *Science*, *Past Global Changes Magazine* (fig. 3), and *Rolling Stone*.

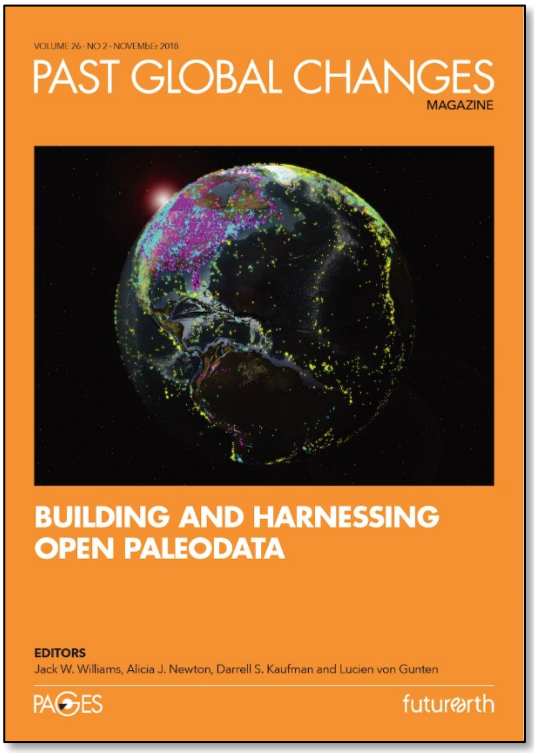


Figure 3. Cover preprint for the *Past Global Changes Magazine* special issue, Building and Harnessing Open Paleodata, was designed by Tanya Buckingham and the University of Wisconsin Cartography Lab. The depicted sample data points the current coverage of PANGEA, National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, and Neotoma Paleoecology Database. The open access issue is available at http://pastglobalchanges.org/products/pages-magazine/12705.

Each year, the Cart Lab hosts an all-day mapping event called the Design Challenge, which draws 20–25 students. For the past three years, the Cart Lab has worked with community partners to create data products and visual stories to advocate for marginalized local populations and associated support networks. In 2017, the Cart Lab worked with Bridge Lakepoint Waunona Neighborhood Center of Madison to advocate for a new community center and improved community support services. Maps and graphics from the event were included in a planning proposal that recently was funded by the City of Madison for over US$2 million. In 2018, the Cart Lab worked with United Way of Dane County to reduce return-to-prison rates and provide services for the successful reintegration of previously incarcerated individuals into the community. The Cart Lab has continued to provide services to the United Way in support of its new Journey Home program. Most recently, in 2019, the Cart Lab partnered with the Urban Underground program to explore the experience of segregation in Milwaukee and provide youth a voice through visualization and video documentaries. Such community partnerships facilitate conversations about diversity within the Geography Department and promote an inclusive environment among our student participants that translates to greater diversity in other cartography activities at UW−Madison.

Conclusion

We seek curricular updates for our cartography programs and courses every two or three academic cycles and will continue to release updated materials and host workshop events through our cartography units, including the Robinson Map Library and University of Wisconsin Cartography Lab. We encourage prospective students, collaborators, and visiting scholars to contact faculty and staff about new and ongoing opportunities in cartography at the UW−Madison Geography Department.

References

Roth, R. E. 2016. "Rethinking Cartography Curriculum to Train the Contemporary Cartographer." In *Proceedings, 6th International Conference on Cartography and GIS, 13–17 June 2016, Albena, Bulgaria*, Bandrova, T., and M. Konecny (eds.), 155–166.

Cartography at the University of Oregon InfoGraphics Lab

James E. Meacham *, Alethea Y. Steingisser, and Joanna R. Merson

University of Oregon, James E. Meacham, jmeacham@uoregon.edu, Alethea Y. Steingisser,, asteingi@uoregon.edu, Joanna R. Merson, jmerson@uoregon.edu

* Corresponding author

Keywords: Atlases, Design, Wildlife, Time charts, Web mapping

Abstract

The InfoGraphics Lab is a cartography and geospatial technology facility housed in the University of Oregon Department of Geography. The InfoGraphics Lab specializes in cartographic design and production for maps and atlases, development of web mapping applications, and public service cartography. This report focuses on three projects in these specialty areas: 1) *Wild Migrations: Atlas of Wyoming's Ungulates*, 2) The Time Charts of Joseph Priestley: A Digital Exploration, and 3) Tsunami Evacuation Route Maps.

Introduction

The InfoGraphics Lab is a cartography and geospatial technology facility housed in the University of Oregon Department of Geography. The InfoGraphics Lab serves the University community, state and local government agencies, and non-government organizations through the application of innovative geospatial technologies, cartographic design, and geographic information science. The InfoGraphics Lab supports research, instruction, and public service activities at the University through a range of involvement from stand-alone consultations to multi-year collaborations. A key aspect of the InfoGraphics Lab is that undergraduate and graduate staff are involved in every project, thus gaining valuable professional experience. Many of these students have gone on to jobs at notable organizations like the National Geographic Society, the *New York Times*, Esri, and Apple.

The InfoGraphics Lab has three specialization foci: cartographic design and production for maps and atlases, development of web mapping applications, and public service cartography. This report focuses on three recent projects in those specialty areas: (1) *Wild Migrations: Atlas of Wyoming's Ungulates*; (2) "The Time Charts of Joseph Priestley: A Digital Exploration"; and (3) the *Beat the Wave Tsunami Evacuation Routes* maps.

Atlas Cartography—*Wild Migrations: Atlas of Wyoming's Ungulates* and *Atlas of Yellowstone*

Since its founding in 1988 (by geography professor Bill Loy and graduate student Jim Meacham), the InfoGraphics Lab has focused on atlas design and production.

The InfoGraphics Lab has produced and published several award-winning atlases over the years including *Atlas of Oregon*, second edition, in 2001; *Atlas of Oregon,* CD-ROM version, in 2002; *Archaeology and Landscape in the Mongolian Altai: An Atlas* in 2010; and *Atlas of Yellowstone* in 2012.

The atlas-making tradition has continued with the fall 2018 publication of *Wild Migrations: Atlas of Wyoming's Ungulates*, a six-year effort with collaborators from the Wyoming Migration Initiative (WMI) at the University of Wyoming. *Wild Migrations* received The Wildlife Society's 2019 Wildlife Publication Award and the Cartography and Geographic Information Society's Best of Show and Best Atlas awards.

The goals in producing the *Wild Migrations* atlas were to help draw attention to the amazing journeys of Wyoming's migratory ungulates, to synthesize disparate spatial data on migration, and to elevate awareness of this ecological phenomenon—migration—as a means of advancing conservation and management efforts. The atlas tells the migration story of Wyoming's big game animals, including their ecology, threats, and conservation efforts and opportunities. The InfoGraphics Lab's staff built hundreds of new cartographic data visualizations using spatial and temporal data of the ungulates from GPS collar data and other location-based technologies. New insights into the migration behavior of big game animals and the corridors they depend on were revealed. For example, animals are migrating much farther than previously known. The longest mule deer migration in the world, the Red Desert to Hoback (RDHB) migration (see figure 1), was discovered by WMI research associate Hall Sawyer during the production of the atlas.

In addition to the creation of maps and data graphics for the *Wild Migrations* atlas, the InfoGraphics Lab, in collaboration with WMI, has created maps for films, social media, and other press outlets, including an animated map in a short documentary film of the RDHB mule deer migration discovery. The film is showcased by National Geographic Society and has had nearly 7 million views (Riis 2014).

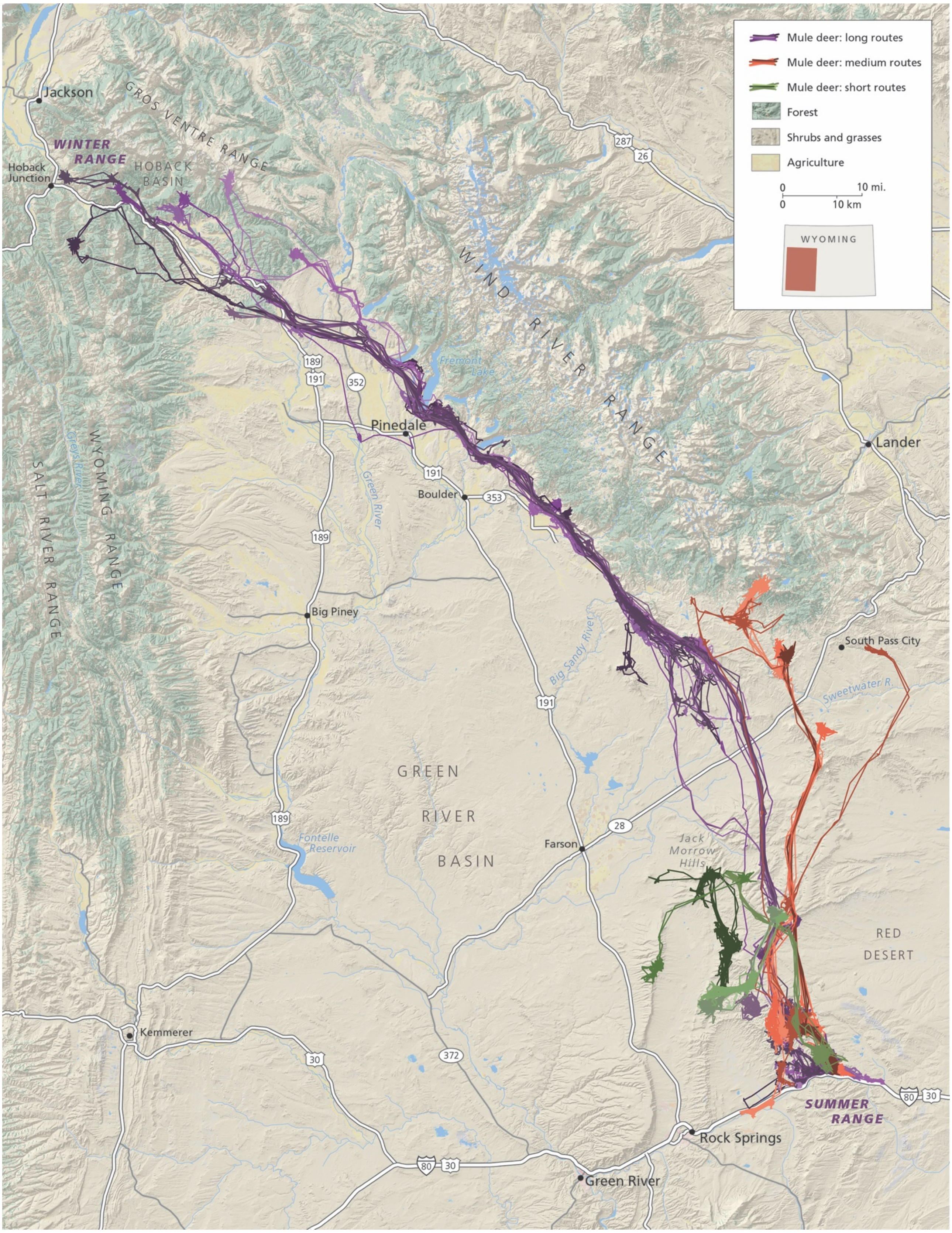


Figure 1. Compiled and mapped WMI GPS collar data led to the discovery of the longest mule deer migration in the world, as shown on the *Red Desert to Hoback Mule Deer Migration* map in *Wild Migrations: Atlas of Wyoming's Ungulates*.

The InfoGraphics Lab is currently working on the development of a second edition of *Atlas of Yellowstone*. The second edition of *Atlas of Yellowstone* will celebrate the history of the world's first national park and coincide with its 150th anniversary in 2022. It will build on the central overlapping themes explored in the first edition: (1) that what happens in Yellowstone is inextricably intertwined with—connected to—landscapes and actions far beyond its borders; (2) that Yellowstone is dynamic and ever changing; (3) that humans are as much a part of the ecosystem as wildlife and natural features are; and (4) that Yellowstone is extraordinary, a wondrous place worth preserving. In light of the 150th anniversary, the second edition will introduce a fifth theme: Yellowstone's reach. This new theme is related to Yellowstone's interconnections, but it goes far beyond. In the 150 years of Yellowstone's park history, the science that originated in the park has revealed and influenced a great deal about perspectives on conservation, preservation, wilderness, and ecosystem science.

Web and Interactive Mapping—"The Time Charts of Joseph Priestley"

Supporting faculty research is a key mission of the InfoGraphics Lab. The InfoGraphics Lab is collaborating with University of Oregon history professor Daniel Rosenberg on his research project, an application called "The Time Charts of Joseph Priestley: A Digital Exploration." Together, the team is transforming Joseph Priestley's 1765 Chart of Biography and his 1769 New Chart of History into interactive graphics. Priestley, a prominent scientist and theologian, created what are arguably the first modern timelines, and his New Chart of History is one of the most influential artifacts in not only historiography but also the history of infographic design.

By creating digital versions of the charts, using a data-driven process, the goals are to (1) facilitate interactive exploration of the charts, (2) analyze Priestley's methods of infographic design in themselves and in relation to modern graphic techniques, and (3) investigate the assumptions Priestley made about the world when he created the charts.

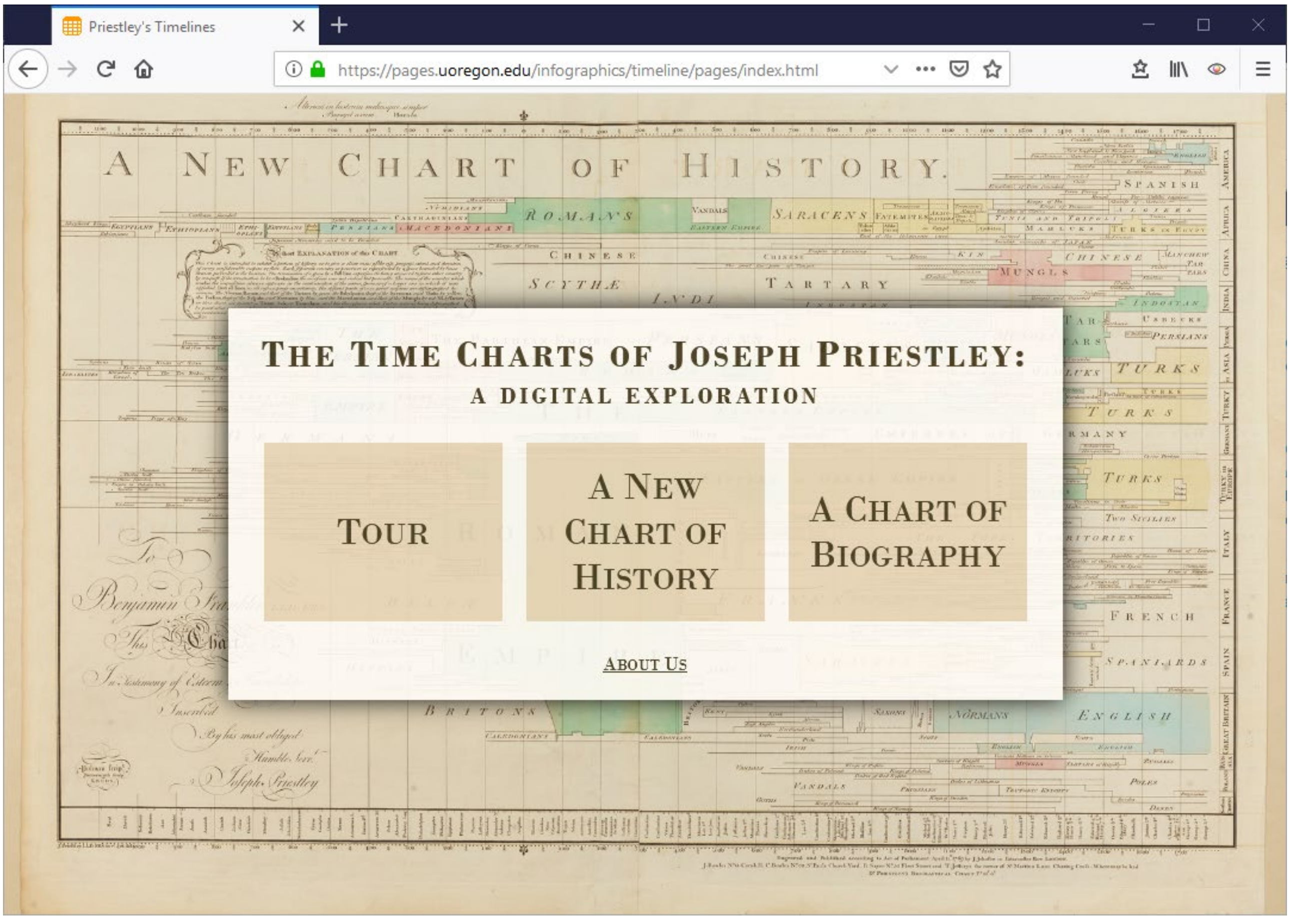


Figure 2. The online app, "The Time Charts of Joseph Priestley: A Digital Exploration," is shown above.

Public Service Cartography—*Beat the Wave Tsunami Evacuation Routes*

The InfoGraphics Lab partnered with the Oregon Department of Geology and Mineral Industries (DOGAMI) to design a template for evacuation routing maps for coastal Oregon communities. According to DOGAMI, an offshore earthquake known as a Cascadia subduction zone event will inundate the West Coast within tens of minutes, and survival for the majority of the population will require spontaneous evacuation on foot (Gabel 2017). The InfoGraphics Lab's staff worked with DOGAMI to identify the most important information that would need to be communicated: where to go and how fast to travel to beat the wave. Then, through an iterative process, the InfoGraphics Lab established a template for the wayfinding maps that would be coordinated with—yet differentiated from—a related set of inundation maps. This template, which includes geographic information system (GIS) processes and design style sheets, will be applied to 15 coastal communities, contributing to the safety of over 40,000 inhabitants.

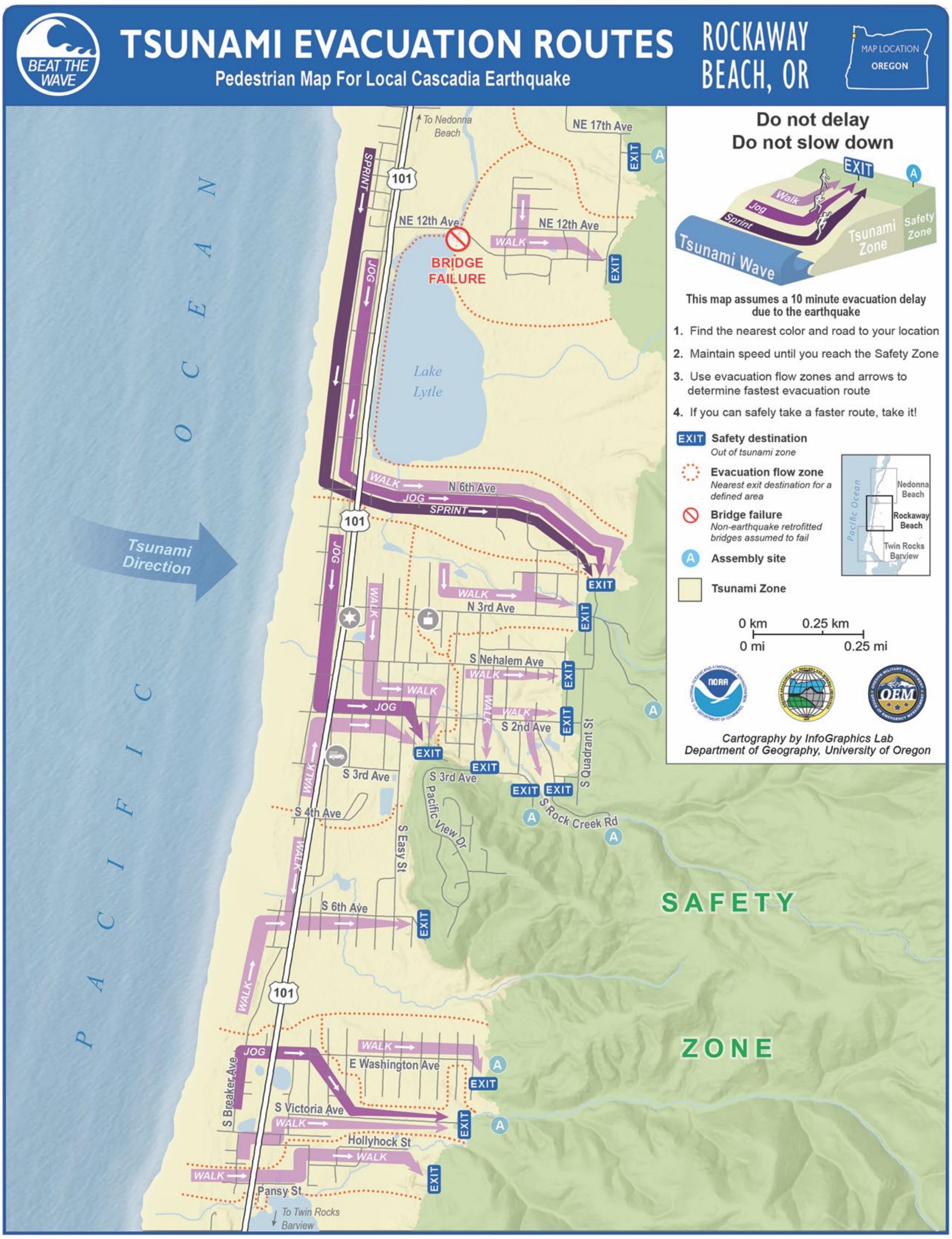


Figure 3. Designing the *Beat the Wave Tsunami Evacuation Routes* maps involved a process of taking complex modeled travel time evacuation route data and developing an easy-to-interpret map template featuring pedestrian travel routes and the speed modes needed for survival, along with tsunami inundation and safety zones and exit points.

Conclusion

Maps, atlases, and web applications that successfully communicate complex science are at the heart of the cartographic work at the InfoGraphics Lab. Designing maps and data visualizations that are compelling, are easy to read, and contribute to increased understanding is a goal that the InfoGraphics Lab constantly strives to achieve. This charge has successfully sustained the InfoGraphics Lab for more than 30 years, will continue to evolve along with technological advances, and will sustain the InfoGraphics Lab into the future.

References

Gabel, Laura L. S., and Jonathan C. Allan. 2017. *Open-File Report O-17-06, Local Tsunami Evacuation Analysis of Rockaway Beach, Tillamook County, Oregon*. State of Oregon, Oregon Department of Geology and Mineral Industries.

Jacobson-Tepfer, Esther, and James E. Meacham. With photos by Gary Tepfer. 2010. *Archaeology and Landscape in the Mongolian Altai: An Atlas*. Redlands: Esri Press.

Kauffman, Matthew, James E. Meacham, Hall Sawyer, Alethea Steingisser, Bill Rudd, and Emilene Ostlind. 2018. *Wild Migrations: Atlas of Wyoming's Ungulates*. Corvallis: Oregon State University Press.

Loy, William G., Stuart Allan, Aileen R. Buckley, and James E. Meacham. 2001. *Atlas of Oregon*, second edition. Eugene: University of Oregon Press.

Marcus, W. Andrew, James E. Meacham, Ann W. Rodman, and Alethea Y. Steingisser. 2012. *Atlas of Yellowstone*. Berkeley: University of California Press.

Marcus, W. Andrew, James E. Meacham, Ann W. Rodman, Alethea Y. Steingisser, and Justin Menke. *Atlas of Yellowstone*, second edition. Place: Publisher, forthcoming.

Meacham, James E., and Erik B. Steiner, eds. 2002. *Atlas of Oregon*. Eugene: University of Oregon Press. CD-ROM.

Riis, Joe, prod. and dir. of photog. *A Deer Migration You Have to See to Believe*. 2014; Laramie, WY: Wyoming Migration Initiative, University of Wyoming. Part of National Geographic Short Film Showcase, April 22, 2014. https://video.nationalgeographic.com/video/short-film-showcase/00000145-8565-d4b0-adcd-adfd8c6d0000.

Rosenberg, Daniel. 2007. "Joseph Priestley and the Graphic Invention of Modern Time." *Studies in Eighteenth-Century Culture*, 36:1, 55–103. Project MUSE. doi: 10.1353/sec.2007.0013

Rosenberg, Daniel, and Anthony Grafton. 2010. *Cartographies of Time: A History of the Timeline*. New York: Princeton Architectural Press.

Rosenberg, Daniel, and Joanna Merson. 2019. "The Time Charts of Joseph Priestley: A Digital Exploration." Infographic. Last modified May 29, 2019. https://pages.uoregon.edu/infographics/timeline/.

Auditory Thematic Maps

Megen Brittell

University of Oregon, megen@uoregon.edu

Keywords: Thematic maps, Audio, Spatial pattern

Abstract

Auditory maps are relatively new tools for communicating geospatial data. To promote the use of audio in cartographic design, I designed, implemented, and evaluated symbology for auditory thematic maps (Brittell 2018a; Brittell 2018b). The design process balanced a theory-based study of dimensionality with the feasibility of producing auditory maps. Evaluation of the resultant maps used neuroimaging methods to measure differences in listener responses to the maps. Analysis revealed a stronger neural response to the symbology that encoded information on multiple audio dimensions when compared to a simpler encoding. An observation was that a general scarcity of auditory thematic maps is bounded not by insufficient technical capabilities but by a lack of experience in designing and listening to auditory maps. I believe audio has much to contribute to the communication of geospatial data, and now is the time to explore this frontier of cartography.

Introduction

The widespread availability of sound cards for audio synthesis and speakers for sound delivery provides both opportunities and challenges in cartographic design. This technology supports sonification that encodes data in nonspeech sound (Dubus and Bresin 2013) and is designed for perception through the sense of hearing. Human hearing is recognized for its ability to perceive patterns (Wojtczak et al. 2017; Hadhazy 2014). As one purpose of thematic maps is to communicate spatial patterns (Montello 2002; Robinson 1986; Robinson et al. 1995), the ability to perceive patterns through hearing makes audio an auspicious option for thematic map display. The use of audio to augment visual displays is gaining popularity (Brauen 2014), but stand-alone auditory displays are still relatively rare. In contemporary cartography, auditory thematic maps have yet to attain widespread use, and there are few established guidelines for the design of effective auditory symbology for thematic maps. My research investigated the design and evaluation of auditory map symbology. Specifically, I explored the influence of organization in the temporal dimension on the perception of spatial information from auditory maps.

Auditory Thematic Map Design

One part of the cartographic design process is the alignment of data with map symbols. Map design—regardless of the display modality—necessarily starts with geospatial data. Map artifacts contain less information than the raw data does—for example simplification and generalization (Robinson et al. 1995)—and those choices optimize the result for the map's intended use and display. In the case of graphic maps, the target is the human visual system; for auditory maps, the target is human hearing. Distinction between these sensory systems is important. The design of auditory representations needs to avoid translation from a map visualization, which could negatively impact the resultant design (Frauenberger et al. 2005), starting instead with the underlying geospatial data.

The design process supporting this research involved exploring the alignment of the dimensions of geospatial data with those of auditory display (Brittell 2018a). Dimensions of geospatial data include space, time, and attribute—for example, a geographic data cube (Berry 1964). Map display dimensions similarly include space, time, and attribute (with the manifestation of those dimensions dependent on the display modality). Some implications for a symbol assignment that stays within one of those categories could differ from those associated with an assignment that crosses category boundaries (and those implications may differ between graphic and auditory maps). As with a graphic symbology, the design of auditory map symbology—and sonification more generally (Asquith 2013)—assigns data dimensions to display dimensions as an expression of both science and art.

Through my research I developed three auditory thematic map designs, which focused on how data was assigned to the temporal dimension of the auditory display. One map design encoded data values as loudness changes in a sequence of musical notes, which was similar to an approach that has been described in literature (Zhao 2008). The spatial location was encoded in time as a virtual cursor that traverses geographic space and follows a pre-determined scan pattern. The attribute value was encoded as loudness. A second map design augmented each note, which still encoded a data value as amplitude, with location data. The spatial location was redundantly encoded in time and in pitch-note rate pairs. The third map design used the augmented note design, which encoded attribute and location in each note, but compressed the collection of notes in time. Notes representing data values at multiple locations were allowed to overlap in time. These three map designs represent one approach to design (for additional details, see Brittell 2018a and Brittell 2018b; example auditory maps are available at https://www.youtube.com/watch?v=Fuu4zVfrLLA, Brittell, 2017) but by no means capture the full spectrum of available design choices, nor do these particular maps address all aspects of map communication—for example, overlay and proximity (Golledge 2002). Still, these auditory thematic maps were artifacts that can be shared, heard, and evaluated.

Evaluating Auditory Maps

Owing to the nearly ubiquitous presence of graphic displays of maps, the design and interpretation of geospatial data displays carry a visual bias. Vision-based strategies permeate the ways that I—a sighted person—have interacted with spatial data. However, spatial information is not inherently visual, one example being amodal spatial representations (Schinazi 2015). Audio has great potential as a display medium for multidimensional data. As part of an effort to distance the empirical evaluation from visual bias, I employed neuroimaging methods in my research (Brittell 2018b). The choice of evaluation method did constrain some design choices, but it provided a unique perspective through which to investigate differences between map types.

Participants received a one-hour introduction to the auditory map designs, and then completed a map listening task while in a functional magnetic resonance imaging (fMRI) scanner. Analysis of the fMRI data revealed that a multivariate encoding (the augmented map design) correlated with a stronger neural response in the bilateral visual cortex and right insula than the neural response with univariate encoding (Brittell 2018b). These data do not reveal why the responses were different, but it provides evidence from sighted listeners that a richer auditory display—one that encodes more data in each note—corresponds with increased brain activity.

Future Directions

To move forward with auditory thematic map design, creative pursuit of auditory map symbology and empirical studies of map listening will both be needed. With early support for rich symbology, it is an open question how best to leverage the large number of available dimensions of audio—for example, Dubus and Bresin (2013) describe 32 dimensions. Novel auditory map design—and I so look forward to hearing more maps!—will need to find new ways to encode geospatial information and to evaluate the resultant auditory maps. Cartographers' expertise in reasoning about and creating abstract representations of geospatial data will be vital to the development of guidelines for audio cartography and to the adoption of sonification techniques into the cartographic toolbox.

Acknowledgements

I would like to thank my advisors and doctoral dissertation advisory committee for their support and guidance, which helped shape this research. This research was supported in part by the Doctoral Dissertation Research Improvement Grant (no. 1634068) from the National Science Foundation, and the University of Oregon Lewis Family Endowment.

References

Asquith, L. Recorded December 9, 2013, in Zurich, Switzerland. "Listening to Data from the Large Hadron Collider." TEDxZurich video. https://www.youtube.com/watch?v=iQiPytKHEwY.

Berry, B. J. L. March 1964. "Approaches to Regional Analysis: A Synthesis." *Annals of the Association of American Geographers* 54, no. 1: 2–11. http://www.jstor.org/stable/2569459.

Brauen, G. 2014. "Interactive Audiovisual Design for Cartography: Survey, Prospects, and Example." In *Developments in the Theory and Practice of Cybercartography: Applications and Indigenous Mapping*, second edition, edited by D. R. F. Taylor, volume 5: 141–159. Elsevier. doi: 10.1016/B978-0-444-62713-1.00010-6.

Brittell, M. 2018a. "Seeking a Reference Frame for Cartographic Sonification." *The 24th International Conference on Auditory Display (ICAD 2018)*. http://hdl.handle.net/1853/60082.

Brittell, M. 2018b. "Neuro-Imaging Support for the Use of Audio to Represent Geospatial Location in Cartographic Design." PhD thesis, University of Oregon–Eugene, December 2018. https://pqdtopen.proquest.com/pubnum/13420194.html.

Brittell, M. 2017. Oregon's Population Depicted in Audio: Temporal Considerations in the Design of Auditory Map Displays (Poster). North American Cartographic Information Society Annual Meeting. Montréal, Quebec, Canada.

Dubus, G., and R. Bresin. December 2013. "A Systematic Review of Mapping Strategies for the Sonification of Physical Quantities." *PLoS ONE* 8, no. 12. doi: 10.1371/journal.pone.0082491.

Frauenberger, C., V. Putz, R. Hoeldrich, and T. Stockman. 2005. "Interaction Patterns for Auditory User Interfaces." In *Proceedings of ICAD 05—Meeting of the International Conference on Auditory Display, Limerick, Ireland, July 6–9, 2005*, edited by E. Brazil: 154–161. http://hdl.handle.net/1853/50161.

Golledge, R. G. 2002. "The Nature of Geographic Knowledge." *Annals of the Association of American Geographers* 92, no. 1: 1–14. doi: 10.1111/1467-8306.00276.

Hadhazy, A. April 2014. "Heavenly Sounds: Hearing Astronomical Data Can Lead to Scientific Insights." *Scientific American*. https://www.scientificamerican.com/article/heavenly-sounds-hearing-astronomical-data-can-lead-to-scientific-insights/.

Montello, D. R. 2002. "Cognitive Map-Design Research in the Twentieth Century: Theoretical and Empirical Approaches." *Cartography and Geographic Information Science* 29, no. 3: 283–304. doi: 10.1559/152304002782008503.

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

Robinson, A. H. 1986. "The Look of Maps: An Examination of Cartographic Design." *The American Cartographer* 13, no. 3: 280–280. doi: 10.1559/152304086783899881.

Wojtczak, M., A. H. Mehta, and A. J. Oxenham. 2017. "Rhythm Judgments Reveal a Frequency Asymmetry in the Perception and Neural Coding of Sound Synchrony." *Proceedings of the National Academy of Sciences* 114, no. 5: 1201–1206. doi: 10.1073/pnas. 1615669114.

Zhao, H., C. Plaisant, B. Shneiderman, and J. Lazar. May 2008. "Data Sonification for Users with Visual Impairment: A Case Study with Georeferenced Data." *ACM Transactions on Computer-Human Interaction* 15, no. 1:4:1–4:28. doi: 10.1145/1352782.1352786.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

The Earth Is Not Flat: Surface-Adjusted Terrain Metrics to Refine Geospatial Models

B. P. Buttenfield [a, *], Y. Qiang [b], M. Ghandehari [c], and G. Charisoulis [a]

[a] *Department of Geography, University of Colorado, Boulder* babs@colorado.edu, *G. Charisoulis,* gech8478@colorado.edu
[b] *Department of Geography, University of Hawai'i, Mañoa,* yi.qiang@hawaii.edu
[c] *Medici Land Governance, Salt Lake City, Utah* mghandehari@mediciland.com

* Corresponding author

Keywords: Terrain analysis, Hazards modeling, Distance metrics, Surface area, Interpolation

Abstract

Advances in computer processing speeds and the emergence of very large ("big data") digital elevation models (DEMs) warrant reexamination of existing conventions for measuring distance and related terrain derivatives on DEMs. The incorporation of slope and other terrain derivatives provides *surface-adjusted* estimates that can improve the accuracy of results for many geospatial modeling applications. This article summarizes the work of a team of researchers over the past four years to establish relationships between estimation methods; spatial resolution; and terrain characteristics and accuracy of estimated elevation, distance, and surface area. The team is adding new members to apply these findings to specific modeling tasks.

Why Is Surface Adjustment Important for Terrain Metrics?

Digital elevation models (DEMs) guide scientists and planners whose work impacts society, safety, and resource management. For example, natural hazard scientists use DEMs to model flooding risk. The analysis of soil moisture and composition and terrain is used to monitor nonpoint source surface pollution and transport of nitrogen and phosphates. Ecologists delineate habitats and nesting territory. Assessing avalanche risk using solar insolation metrics is based on slope and aspect. Network analysis incorporates DEMs to model cost path analysis of freight transport. Telecommunications networks (cell towers) are situated on terrain to provide line-of-sight connectivity. Social scientists incorporate terrain data dasymetrically to refine estimates of population density or assess service accessibility.

The basic terrain derivatives include slope, aspect, roughness, and curvature—all directly computed from distance metrics. By convention, distance is measured on DEMs between pixel centroids, assuming that pixels are rigid and flat, albeit tilted, as if pieces of ceramic tile. Euclidean metrics define a series of "as the crow flies" straight segments between adjacent pixels. The "rigid pixel" paradigm generates basic spatial measurements (distance, direction, area) that are in fact somewhat imprecise. Working at very fine spatial resolution (e.g. ground-based lidar), the degree of imprecision is quite small, but as pixel sizes increase (with continental or global spatial extent modeling), errors accrue at increasing rates (fig. 1).

Compromised distance estimates can corrupt higher-dimensional measurements (area and volume), and these can bias measures of proximity, neighborhood size, spatial dependence, etc. The consequences of chronic misestimation have clear societal implications on sea level rise estimation and risk to populations, economic consequences for routing costs, and other problem domains. These consequences become more compelling when modeling rural or developing areas (the "global south") where lidar data is not always available. With advances in geoprocessing speed and wide availability of fine-resolution terrain data, it has become pragmatic and feasible to refine estimates of distance and other terrain derivatives by relaxing the rigid pixel assumption and adopting what our research team calls *surface-adjusted* terrain measurement. We are examining surface adjustment methods to reduce error and uncertainty relating to estimating elevation, distance, and area across spatial resolutions and various terrain conditions. Usery et al. (2003) demonstrated that computations on the sphere substantially improve with planar measurements. Preliminary results of our work indicate that surface adjustment could improve geospatial modeling to a similar degree.

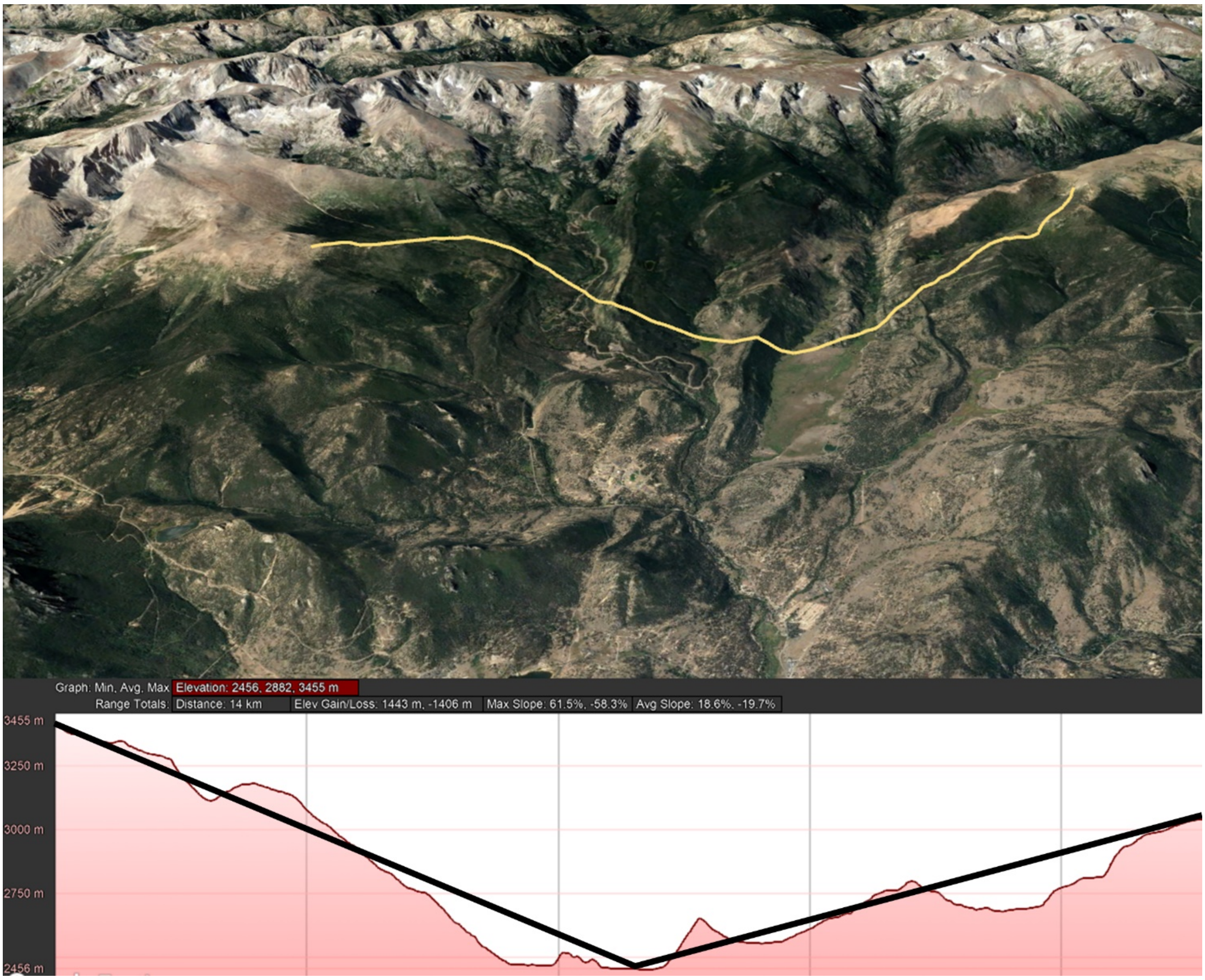


Figure 1. Imagine that the terrain image is captured in only two pixels. Note the difference in length between the rigid pixel Euclidean profile and the actual (red shading) image profile. (Terrain image and profile of Indian Peaks range west of Boulder, Colorado, taken from https://www.google.com/earth/versions/#earth-pro, last visited 10 June 2019. Euclidean approximation added.)

Initial Results of Early Work

Six DEM study areas with varying characteristics of elevation, local relief, slope, terrain roughness (standard deviation of elevations within a 10 by 10-pixel focal window at 10-meter (m) spatial resolution), and terrain uniformity have been tested to estimate elevation, distance, and surface area (table 1). Independent DEM compilations at 10 m, 30 m,100 m, and 1,000 m resolutions were tested using a suite of interpolation methods based on spatial neighborhoods ranging from 1 to 25 pixels (weighted average, closest centroid, TIN, linear, bilinear, biquadratic, and bicubic polynomials), evaluating residuals and root-mean-square error (RMSE) values in comparison with another independently compiled 3 m lidar benchmarks.

Table 1. Morphometric characteristics of the six digital terrain models used in all surface adjustment studies.

Study Area	*Elevation (m)*				*Slope (°)*		*Roughness (m)*		*DEM Size (km^2)*
	Maximum	Minimum	Mean	Std. Dev'n.	Mean	Std. Dev'n.	Mean	Std. Dev'n.	
Washington	2341.15	-0.68	445.04	438.55	15.29	14.39	8.24	7.92	4533.35
Colorado	4225.39	2108.39	2818.50	366.51	12.31	10.35	5.68	4.73	2493.29
North Carolina	1616.97	192.59	442.18	223.07	11.01	9.11	4.87	3.97	7786.72
Nebraska	931.55	635.42	786.70	54.81	5.07	5.45	2.02	1.65	4709.26
Texas	471.28	99.18	225.84	77.94	2.44	3.03	1.09	1.13	5475.28
Louisiana	69.17	-4.87	13.81	12.26	0.92	1.53	0.35	0.44	5307.17

Ghandehari et al. (2019) estimate elevation using point samples that are not coincident with pixel centroids. Surface adjustment might incorporate any or all terrain derivatives. Correlation analysis relating absolute residuals of off-centroid elevation estimates for 20,000 randomly selected points shows the strongest significant relationships with slope (0.617, p=0.001) and terrain roughness (0.612, p=0.000). Curvature shows a weak significant relationship (0.309, p=0.000). Association with aspect is not significant (p=0.960). Estimated elevation errors increase at coarser resolutions, with errors in flatter, smoother terrain on the order of a few centimeters. In these landscapes, the choice of estimation method may not make a difference. In rougher terrains, the biquadratic and bicubic polynomials generate the lowest RMSEs but take nearly three times longer to process. Local Moran's I (LISA) testing (Anselin 1995) indicates spatial clustering of significantly high residuals (p=0.050) in terrain that is rough and nonuniform (fig. 2, left).

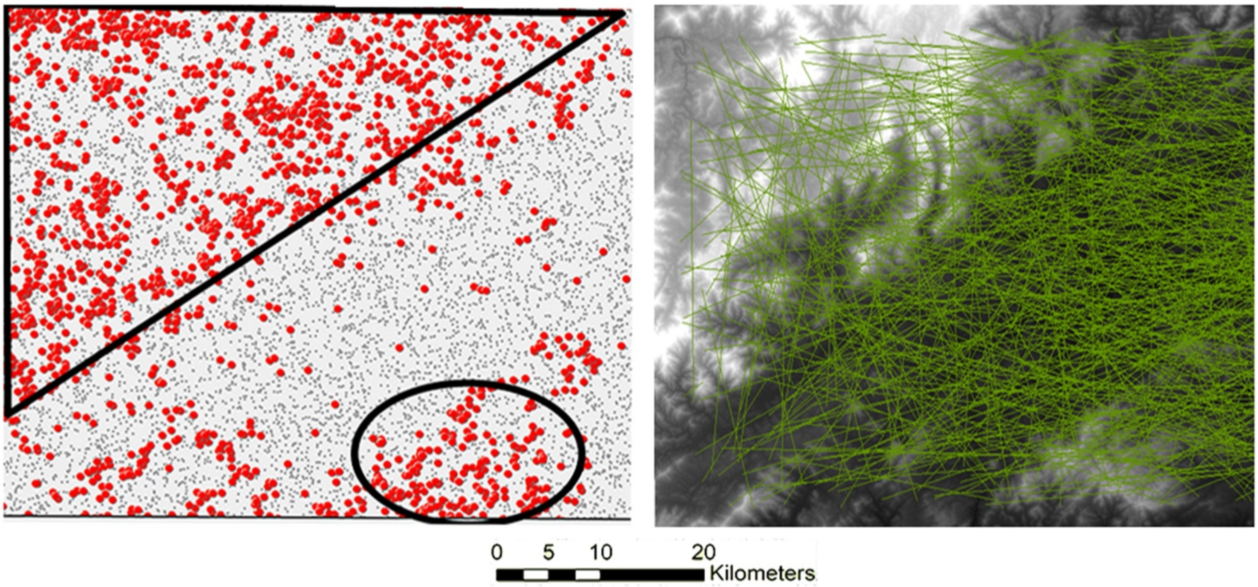


Figure 2. Western portion of the North Carolina study area highlighting rough and nonuniform terrain (paler shading). *Left*, sample of 20,000 points used to estimate surface-adjusted elevations; red samples indicate clusters of points with very high residuals for elevation estimation that are concentrated in rough and nonuniform terrain (black outlines). (Modified from Ghandehari et al. 2019).

Right, DEM overlaid with 1,000 transects for the Monte Carlo simulation in the second distance estimation experiment. (Modified from Qiang et al. 2017.)

Two studies focused on surface-adjusted distance. In a pilot, Buttenfield et al. (2016) estimate distances on a small number of transects positioned manually on the six DEMs, finding that planar and geodesic metrics consistently underestimate benchmark distances relative to surface-adjusted distance. Bilinear and weighted average interpolation estimate distance with the lowest errors (under 3%) across all resolutions. Distance estimation for transects crossing nonuniform terrain (e.g. North Carolina, Washington) are higher than for uniform terrain (including Nebraska, which is uniformly rough) with misestimations reaching above 23 percent for some methods. To refine this study, Qiang et al. (2017) apply a Monte Carlo simulation to 1,000 transects randomly positioned over each DEM (fig. 2, right). Preliminary findings show that RMSEs for the weighted average method are lowest for 10 m and 30 m resolution, and second lowest at 100 m, with the closest centroid, bilinear, and biquadratic polynomials producing the smallest RMSEs at coarser resolutions. This study is ongoing, and full results are not yet available.

A third area of investigation involves the estimation of surface area. Conventionally, surface area is computed from pixel dimensions. Relaxing the assumption of flat pixels leads to more realistic (albeit more complex) computations. Jenness (2004) interpolated among adjacent pixels (fig. 3, left) to generate 8 surface-adjusted triangles that incorporate slope because of each vertex's unique elevation measured at respective pixel centroids. Ghandehari and Buttenfield (2018) modified Jenness' method (fig. 3, right) by estimating elevation at 8 points along the boundary of the pixel in question, comparing five interpolation methods from the suite listed above. Initial findings show that a bicubic polynomial outperforms other methods for improving accuracy, while the bilinear method produces nearly the same RMSE while reducing processing time by up to 80 percent.

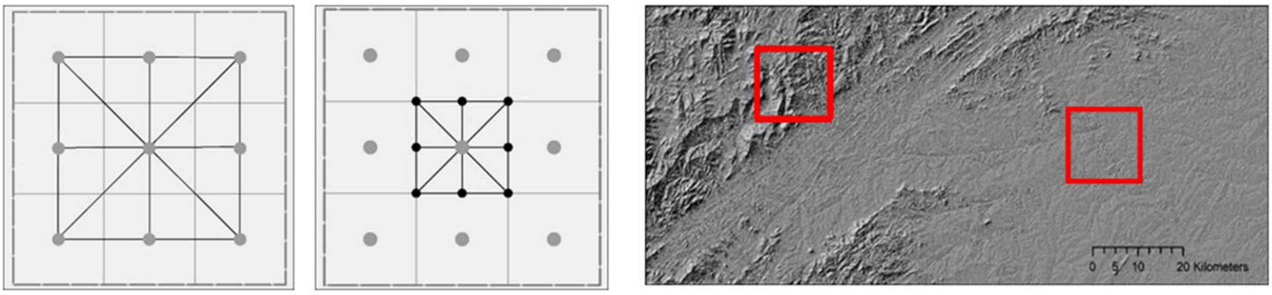


Figure 3. *Left,* comparison of Jenness' (2004) surface adjustment method with Ghandehari and Buttenfield's (2018) modification, which not only increases processing time but also reduces error.

Right, two sampled patches from the North Carolina DEM in uneven and smooth terrain, used in the surface area estimation experiments. (Modified from Ghandehari and Buttenfield 2018).

Summary and Future Research Directions

Research demonstrates that surface adjustment provides DEM-based measurements of elevation, distance, and surface area that approach results for finer resolution data, although results depend on DEM resolution, method of estimation, and terrain uniformity. The choice of an optimal method is a balanced compromise between error reduction and increased processing time and data volume. The choice also varies with estimation task (elevation, distance, or surface area). Current efforts focus on completing the analysis of distance from the Monte Carlo simulation and validating surface area estimations for larger patches of terrain. One application currently under investigation involves freight routing along mountainous road networks. Once estimation methods are established for each type of surface-adjusted estimation that optimally balances accuracy improvement with shorter geoprocessing times, future work will incorporate these into geospatial models currently working or under development. The research team is expanding to include remote-sensing colleagues who build DEMs from interferometric synthetic aperture radar (INSAR) imagery and ground-based lidar, and who have expertise in hazards modeling including flooding, sea level rise, earthquakes, and landslides. The goal is to assess the risks of natural hazards with more reliability.

Acknowledgments

This reports on research for the Data Harmonization Initiative as part of the Grand Challenge at the University of Colorado, Boulder, Earth Lab (https://www.colorado.edu/earthlab/).

References

Anselin, L. 1995. "Local Indicators of Spatial Association—LISA". *Geographical Analysis* 27, 2, 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x.

Buttenfield, B. P., M. Ghandehari, S. Leyk, L. V. Stanislawski, M. E. Brantley, and Y. Qiang. 2016. "Measuring Distance 'As the Horse Runs': Cross-Scale Comparison of Terrain-Based Metrics." *Proceedings of International Conference on GIScience 2016.* Montreal, Canada. https://doi.org/10.21433/B3118rh987cz.

Ghandehari, M. and B. P. Buttenfield. 2018. "Slope-Adjusted Surface Area Computations in Digital Terrain." *Proceedings of Geomorphometry 2018*. August 2018. Boulder, Colorado. PeerJ Preprints 6:e27068v1. https://doi.org/10.7287/peerj.preprints.27068v1.

Ghandehari, M., B. P. Buttenfield, and C. J. Q. Farmer. "Comparing the Accuracy of Interpolated Terrain Elevations Across Spatial Resolution." *International Journal of Remote Sensing* 40, 13, 5025–5049. https://doi.org/10.1080/01431161.2019.1577581.

Jenness, J. S. 2004. "Calculating Landscape Surface Area from Digital Elevation Models." *Wildlife Society Bulletin* 32, 3, 829–839.

Qiang, Y., B. P. Buttenfield, M. Joseph, and C. J. Q. Farmer. "Systematic Evaluation of Surface-Adjusted Distance Measurements Using an HPC-enabled Monte Carlo Simulation." *Association of American Geographers Meeting*. April 5–9. Boston, Massachusetts.

Usery, E. L., M. P. Finn, J. D. Cox, T. Beard, S. Ruhl, and M. Bearden. 2003. "Projecting Global Datasets to Achieve Equal Areas." *Cartography and Geographic Information Science.* 30, 1, 69–79.

International Cartographic Association
Association Cartographique Internationale
Cartography and Geographic

Evaluating Thematic Tactile Maps for Risk Assessment

Harrison Cole

Department of Geography, The Pennsylvania State University, harrisoncole@psu.edu

Keywords: Tactile maps, Accessibility, Risk, Natural hazards, Heuristic evaluation

Abstract

United States law states says that federally published information must be accessible to people with disabilities, including those who are blind or visually impaired. This poses a challenge with regard to maps. The current, most popular solution among federal agencies is to provide written descriptions of the maps and/or features contained therein. However, written or verbal descriptions lose or obfuscate spatial relationships among features on a map, making any sort of analysis or evaluation difficult or impossible to perform. This article proposes using thematic tactile maps as an alternative means of making spatial information accessible to people with visual disabilities. Using flood risk assessment as a scenario, tactile maps can be analyzed using heuristic evaluation based on federal guidelines. The results of such a study would provide critical insight into the design and usability of thematic tactile maps, an aspect of accessible cartography that, in consideration of aging populations and increasingly frequent natural disasters, is in urgent need of further investigation.

Introduction

Over the last three decades, significant efforts have been made to ensure that federally distributed information is accessible to people with disabilities. In particular, Section 508 of the Rehabilitation Act of 1973 requires government agencies to publish information in a format that is both accessible to people with disabilities and comparable to information accessible to people without disabilities (United States Access Board 2000). Methods for compliance may take the form of large type, high-contrast graphics, or web pages designed to be compatible with screen readers. In the event that full compliance cannot be achieved without imposing an "undue burden" on the agency, information must be published using "alternative means" (United States Access Board 2000). The definition of this phrase is deliberately open-ended but is meant to imply the use of methods similar to those listed previously. While textual information may be easily communicated using a screen reader or Internet messaging service, for instance, a map presents a much more substantial challenge, in particular for people who are blind or profoundly visually impaired (B/VI hereafter)—that is, cases in which even large type or high-contrast colors would be insufficient. The solution for these instances has most frequently been to provide written or verbal descriptions of the maps (World Wide Web Consortium 2008; HHS.gov 2009; Esri 2018).

The issue for B/VI users is that Section 508 standards are not designed to preserve thematic spatial information as such. A Section 508-compliant map could technically fulfill the required standards merely by labelling features but without providing any means for understanding relationships among features or patterns of their presence. For example, Flood Insurance Rate Maps (FIRMs) published by the Federal Emergency Management Agency (FEMA) depict the extent and risk of flooding in cities across the United States (fig. 1). The complexity of each map is such that a comprehensive written (or verbal) description would be very impractical to write (or articulate). Furthermore, using a description of a FIRM for community hazard risk—in which one would be concerned with dozens of features including complex, sometimes amorphous thematic data—could be prohibitively difficult for someone who is B/VI. In response, we are outlining research to investigate the use of tactile media for creating Section 508-compliant maps that can be used as maps per se. This research would fill a critical gap in cartographic literature; the vast majority of research on tactile maps has focused on wayfinding, but there has been little research conducted on *thematic* tactile maps (Lawrence and Lobben 2011; Lobben 2005). A proposed study to tackle this challenge would use the context of community hazard risk assessment to evaluate thematic tactile risk maps against current practices, namely map descriptions. The results of such a study can offer insights into the design and use of thematic tactile maps, as well as suggestions for the development of federal tactile graphics standards.

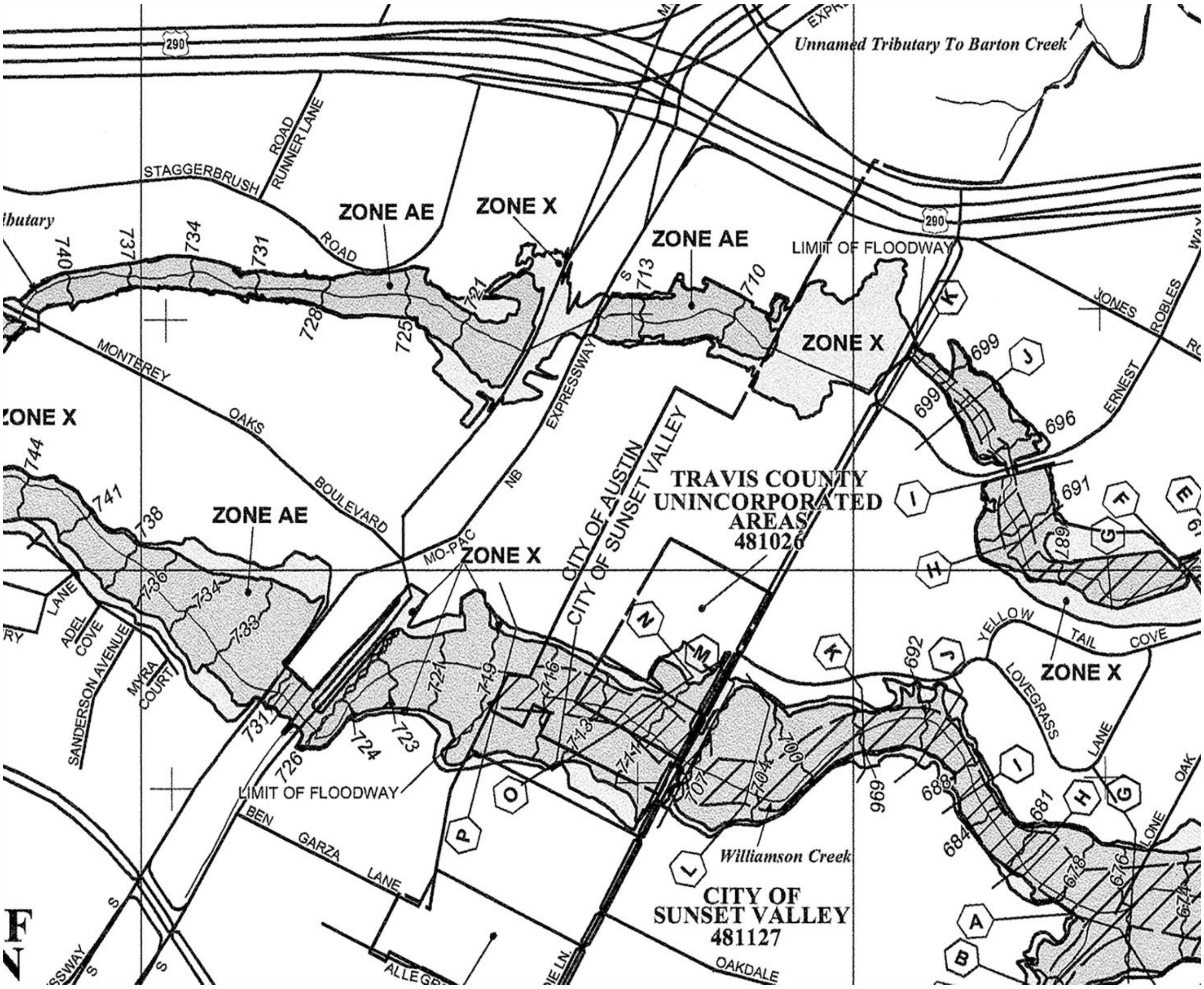


Figure 1. Detail of FIRM 48453C0580H depicting flood risk in a section of Austin, Texas. Courtesy FEMA Flood Map Service Center.

An Approach for Evaluating Tactile Maps for Risk Assessment

One way to address these challenges is to use heuristic evaluation to examine a B/VI user's ability to perform a hazard risk assessment using thematic tactile maps both on their own and in a collaborative setting. While there exist several methods and materials for creating tactile maps, microcapsule paper printing is one of the most inexpensive and widely available options, meaning that people can access it at home (Rowell and Ungar 2003; Lawrence and Lobben 2011). Transcription of FIRMs into a tactile format could follow standards developed jointly by the Braille Authority of North America and the Canadian Braille Authority (2010). After these tactile maps are created, B/VI study participants can be asked to perform, individually, a highly condensed, map-focused version of the four-step risk assessment process as outlined by FEMA, which entails describing the character of hazards, identifying community assets, analyzing risks (impacts), and summarizing community vulnerability (Federal Emergency Management Agency 2013). Each step of this process would include an assessment scale for participants to rank their findings (level of vulnerability, value of community assets, etc.) based on recommendations or examples provided by FEMA (2013). A control group can then be asked to perform the same tasks using descriptions of maps written in the style that would be available from FEMA under Section 508 guidelines. This experiment can then be repeated with pairs consisting of one B/VI participant and one sighted participant working together using a tactile map and a FIRM. The control group would have sighted participants describe FIRMs to B/VI participants. These collaborative group experiments are designed to lend insight into how tactile maps might (might or not) be used in real-world risk assessment scenarios.

Conclusion

It will become increasingly important for disaster management practices to incorporate people who are B/VI, as the number of people with visual impairments increases, potentially doubling in the United States by 2050 (Varma et al. 2016). The increasing frequency and severity of natural hazards under global climate change (Pachauri et al. 2014) will put these populations at even greater risk than before. This work identifies a potential methodological mechanism for assessing the potential impacts of these hazards for an especially vulnerable population. Simultaneously, a fuller understanding of how tactile maps function in goal-oriented scenarios, as well as moving toward accessible map availability being a standard expectation of geospatial services, contributes to a more expansive conceptualization of the roles and capacities of tactile maps—not just as instructive or analytical tools but as expressive, creative tools as well. The normalization of accessible mapping and incorporation of B/VI cartographers into the cartographic process can shift the issue of map accessibility from one of meeting standards *for* people who are B/VI to one of exchanging knowledge *with* people who are B/VI.

References

Federal Emergency Management Agency. Flood Insurance Rate Map 48453C0580H. 2008. From FEMA Flood Map Service Center. Accessed January 21, 2019. https://msc.fema.gov/portal/home.

Esri. *ArcGIS Pro Accessibility Conformance Report*. 2018. esri.com/content/dam/esrisites/en-us/media/legal/vpats/arcgis-pro-23-vpat.pdf.

HHS.gov. "Guidelines and Examples for Determining the Suitability of an Accessibility Accommodation." March 2009. https://www.hhs.gov/web/section-508/accessibility-accomodation/index.html.

Braille Authority of North America. "Guidelines and Standards for Tactile Graphics." 2010. http://www.brailleauthority.org/tg/.

Lawrence, Megan M., and Amy K. Lobben. 2011. "The Design of Tactile Thematic Symbols." *Journal of Visual Impairment & Blindness* 105, no.10: 681–91. doi: https://doi.org/10.1177/0145482X1110501014.

Lobben, Amy K. 2005. "Identifying the Needs of Tactile Map Makers." Proceedings of the 22nd International Cartographic Conference, A Coruña, Spain. http://icaci.org/files/documents/ICC_proceedings/ICC2005/htm/pdf/oral/TEMA22/Session%201/AMY%20LOBBEN2.pdf.

Federal Emergency Management Agency. *Local Mitigation Planning Handbook.* 2013. https://www.fema.gov/media-library-data/20130726-1910-25045-9160/fema_local_mitigation_handbook.pdf.

Pachauri, Rajendra K., Myles R. Allen, Vicente R. Barros, John Broome, Wolfgang Cramer, Renate Christ, John A. Church, Leon Clarke, Qin Dahe, and Purnamita Dasgupta. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: IPCC. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.

Rowell, Jonathan, and Simon Ungar. 2003. "The World of Touch: Results of an International Survey of Tactile Maps and Symbols." *The Cartographic Journal* 40, no. 3: 259–63. doi: https://doi.org/10.1179/000870403225012961.

United States Access Board. "Section 508 Standards." December 21, 2000. https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards/section-508-standards.

Varma, Rohit, Thasarat S. Vajaranant, Bruce Burkemper, Shuang Wu, Mina Torres, Chunyi Hsu, Farzana Choudhury, and Roberta McKean-Cowdin. 2016. "Visual Impairment and Blindness in Adults in the United States: Demographic and Geographic Variations from 2015 to 2050." *JAMA Ophthalmology* 134, no. 7: 802–9. doi: https://doi.org/10.1001/jamaophthalmol.2016.1284.

World Wide Web Consortium. "Web Content Accessibility Guidelines (WCAG) 2.0." December 11, 2008. https://www.w3.org/TR/WCAG20/#perceivable.

International Cartographic Association
Association Cartographique Internationale
Cartography and Geographic Information Society
CaGIS

Moving Toward Immersive VR for Regional Heritage Sites

Sven Fuhrmann *, Alisa Pettitt, and Saíd Ahmed

Department of Geography and Geoinformation Science, George Mason University, Fairfax, VA, Sven Furhmann, sfuhrman@gmu.edu, Alisa Pettitt, apettitt@masonlive.gmu.edu, Saíd Ahmed, ssaidahm@masonlive.gmu.edu

* Corresponding author

Keywords: Geovisualization, Virtual Reality, Heritage Site Education, Archaeological Mapping, Digital Humanities

Abstract

Immersive virtual reality (VR) displays can be powerful for conveying engaging narratives that educate audiences on archaeological sites. Heritage-focused VR applications immerse audiences in multisensory experiences in which they engage with digitized archaeological data through means unfeasible in traditional on-site visits. Much of the three-dimensional (3D) data used to populate VR applications has already been generated as archaeological practice shifts toward incorporating technologies such as advanced photogrammetry software, 3D scanning, and 360-degree video. Harnessing this data to craft 3D geovisualizations that explore the multilayered, rich nature of archaeological sites can aid in communicating new narratives and engaging with audiences of the digital age. This manuscript demonstrates that developing educational virtual heritage site portals is no longer just for internationally recognized historic sites, and it provides an immersive archaeological site example and advocates the close collaboration between cartography, archaeology, and digital humanities in modern geovisualization of heritage sites.

Introduction

Digital humanities is an emerging and diverse domain that studies the practice of humanities research in and through information technologies by assessing how human culture studies could advance through the engagement with digital technologies, media, and computer science (Svensson 2010). Similarly to the field of cartography in the early 1990s, the humanities fields are also challenged with and by the current information technology advancements that have led to several innovations for domain experts and the public (Gasper-Hulvat 2017, Hollander 2018).

Archaeology, a domain that systematically studies material remains of the human past (Society for American Archaeology 2019), applies various mapping techniques at different scales during all stages of archaeological site discovery, assessment, and interpretation. The importance of maps and related geoinformation technologies for archaeological field studies is unquestionable. Archaeological field practice demands a systematic approach involving a thorough comparison of historic recordings (i.e., narratives, sketches, imagery, etc.) with the existing physical landscape.

Between cartography and archaeology, there has always existed a complementary relationship. Understanding human-environment interactions in ever-evolving landscapes is essential for interpreting and understanding cultures, heritage, and history. Mapping in archaeological practice begins before conducting fieldwork through intensive background research, continues during site excavation and interpretation, and concludes in visualizing interpreted findings to archaeologists, historians, anthropologists, the public, and other domains. Mapping and the interpretation of archaeological data are crucial to modern archaeological practice, and findings from investigations without accurate spatial context lose layers of meaning.

Best practices in archaeological mapping have evolved from hand mapping broad site boundaries to pinpointing archaeological data with Global Navigation Satellite System (GNSS) receivers. New tools, such as unmanned aerial vehicles (UAVs), accessible photogrammetry software, and 3D geoinformation technologies combined with traditional cartographic archaeological processes, are resulting in superior visualizations for conveying archaeological information. In particular, the current movement toward collecting and creating three-dimensional data is altering how archaeologists conceive of and present archaeological maps. Three-dimensional archaeological site data provides highly accurate, unbiased heritage site information that can serve a myriad of purposes including, but not limited to, creating engaging geovisualization displays.

Display and mobility advances in immersive virtual reality technologies allow visualizing high-dimensional archaeological data for site discovery, assessment, interpretation, and education. Mobile VR systems (e.g., the low-cost Oculus Go or the Lenovo Mirage Solo) are available in the consumer market, and custom development environments for VR applications have become accessible. These mobile, immersive systems provide opportunities to discover, assess, and interpret multilayered archaeological data, in particular, 3D datasets. Infusing traditional archaeological mapping with new spatial data types in immersive, mobile VR environments is a powerful means of conveying and educating on archaeological resources. VR platforms that allow experts and the public alike to visualize multiple components and data layers of heritage sites offer opportunities to explore archaeological information, heritage, and history on higher levels. Digital preservation, interpretation, analysis, and education on and at archaeological sites can be greatly enhanced through VR technologies. The following example focuses on the education stage of the archaeological process. VR technologies can be harnessed to remedy the disconnect between spatial context and archaeological materials often found in traditional museum exhibits where heritage objects are only shown in glass display cases, disconnected from any locality.

Collaborations between Cartography and Archaeology: A Case Study in Heritage Site Education

Educating about heritage sites is the main component in archaeological practice. Museum educators serve as stewards for presenting and explaining archaeological information. Exhibitions focused on showcasing archaeological objects and sites aim to connect with the public through highlighting special artifacts, cultural lifeways, and rituals through novel and engaging approaches. A major challenge in creating exhibits is identifying which information to show and which media to use. In traditional museum exhibits, information is often presented with a disconnect between archaeological materials and associated provenience. This disconnect stems from early museum exhibition practice in which exhibits served as "cabinets of curiosities" (i.e., displays highlighting interesting materials collected from expeditions) with exhibits often lacking spatial and cultural context. When historic artifacts are separated from their spatial context, the exhibits lose their deeper historic meaning. Failing to present the spatial context in heritage displays demotes the importance of this systematic science and does not communicate a complete picture of the archaeological site, the artifacts, and the narratives.

VR technologies are one possible solution to reconnect and show the spatial context linked to archaeological artifacts in museum exhibits. At its core, VR can enhance a visitor's appreciation of archaeological materials by assisting in visualizing artifacts in realistic environments and informing audiences on the importance of archaeological mapping in field practice. Spatial and cultural context are essential components to archaeological practice, and conveying this notion to the public could aid in better grasping heritage and history. Artifacts spotlighted behind glass cases are beautiful to look at, but this presentation style disregards context, which is fundamental to fully understanding the remains of past civilizations (Barbieri et al. 2017; Pollalis et al. 2018; Schofield et al. 2018).

To highlight these VR-based heritage site education opportunities, a well-known, regional archaeological site in Fairfax County, Virginia, was selected to showcase the educational collaboration opportunities between cartography and archaeology. Riverbend Park draws hundreds of visitors each year but is maintained at the county level. Fairfax County is the most populous jurisdiction in Virginia and has started to invest in immersive VR technologies for archaeological/historic site education.

Riverbend Park

Riverbend Park is about 20 miles northwest of Washington, DC. This park is situated on the Potomac River and contains about 200 archaeological sites, the majority with Native American components. Riverbend Park is vested in presenting educational programs on local Native American histories, with several student camps devoted to instruction on lifeways of Virginia's first peoples and a museum showcasing artifacts from the park.

Riverbend Park is an active heritage site with trails, picnic areas, and boating activities. Thus, many archaeological locations cannot be revealed at the physical site due to potential looting and destruction. To provide the general public with an immersive experience of the local narratives of Native Americans, an application was created following an existing educational trail and program at the park using publicly accessible information. A local member of the Pamunkey and Tauxenant Tribes served as project adviser, adding important narrative perspectives and an indigenous voice.

The VR app focuses on the Early Middle Woodland period (1200 BC–AD 500) with animated characters in period dress and lifelike flora and fauna once found in the park, offering a vivid picture of how Riverbend Park may have been at that time. Several scenes in the VR experience refer to the drawings of John White, who sketched Native American content of the mid-Atlantic region around 1585 (fig. 1).

Figure 1: A dance scene from a John White drawing transferred to the VR Riverbend Park experience.

Through the app, virtual characters interact with artifacts from Riverbend Park. This interaction, along with information about the artifacts and the ability to view the physical specimens in the museum afterward gives audiences the opportunity to learn more about them and how they were used. For example, a gorget from Riverbend Park can be viewed adorning the neck of a virtual character, inspected in detail as a digital model, and then seen in the museum. The VR app provides a unique experience for the public to immerse themselves in and interact with sensitive artifacts and explore and better understand past landscapes and cultures while visiting Riverbend Park (fig. 2).

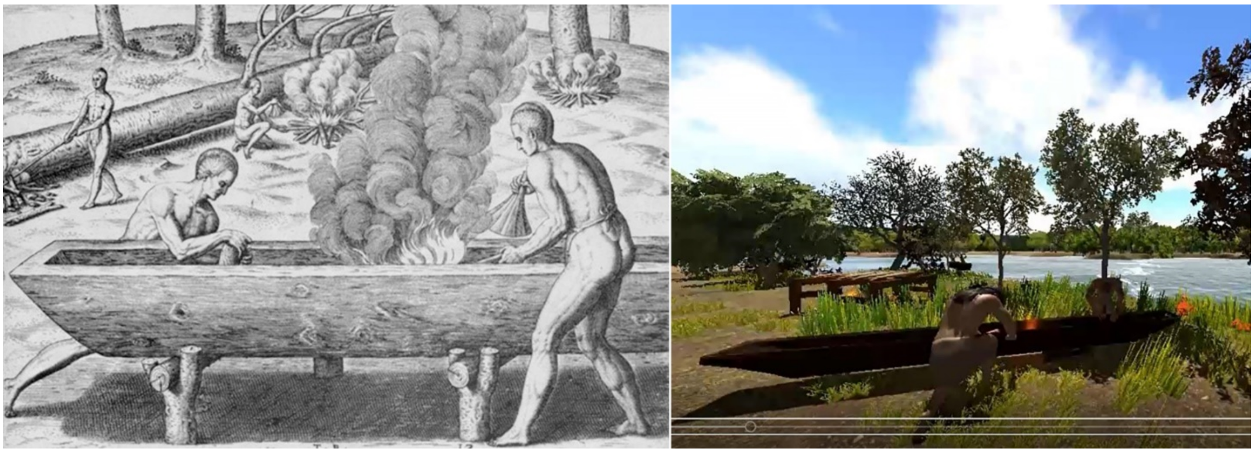


Figure 2: A dugout canoe-building scene from a John White drawing transferred to the VR Riverbend Park experience.

Conclusion

This research demonstrates that developing educational virtual heritage site portals is no longer just for internationally recognized historic sites. The presented case study was realized for a regional historic site that draws hundreds of visitors each year but is maintained at the county level.

This study explores how interactive, immersive VR platforms can assist in connecting broader audiences with narratives on heritage sites and serve as successful vehicles for history education. These technological advances have reached the affordable consumer market and are more accessible to regional heritage sites to introduce effective, innovative geovisualization displays that provide novel, engaging narratives to the public. Through collaboration, the humanistic sciences of cartography, geovisualization, archaeology, and others are well positioned to make significant contributions to new methods and technologies in the digital humanities.

How to incorporate and share accurate location information of sensitive archaeological site data is one issue that requires further investigation. In addition, the current VR application utilizes a walking, first-person viewing perspective for all audiences, and an assessment of whether other viewing perspectives or modes of transportation (e.g., horse or airborne based) might be more suitable or effective will be done in the future. Further research will also focus on evaluating users' sense of place and historic site-specific learning outcomes.

References

Barbieri, L., F. Bruno, and M. Muzzupappa. 2018. "User-centered design of a virtual reality exhibit for archaeological museums." *International Journal on Interactive Design and Manufacturing* 12, no. 2: 561–571.

Burdick, A., J. Drucker, P. Lunenfeld, T. Presner, and J. Schnapp. 2012. *Digital Humanities*. Cambridge: MIT Press.

Gasper-Hulvat, M. 2017. "Active Learning in Art History: A Review of Formal Literature." *Art History Pedagogy & Practice* 2, no. 1. Accessed June 2, 2019. https://academicworks.cuny.edu/ahpp/vol2/iss1/2.

Hollander, M. 2018. "The Imaginary Museum: Teaching Art History with Mobile Digital Technology." *Digital Humanities Quarterly* 12, no. 2. Accessed June 2, 2019. http://www.digitalhumanities.org/dhq/vol/12/2/000390/000390.html.

Pollalis, C., E. J. Minor, L. Westendorf, W. Fahnbulleh, I. Virgilio, A. L. Kun, and O. Shaer. 2018. "Evaluating Learning with Tangible and Virtual Representations of Archaeological Artifacts." *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction,* 626–637. Stockholm, Sweden: ACM Press.

Schofield, G., G. Beale, N. Beale, M. Fell, D. Hadley, J. Hook, and L. Thresh. 2018. "Viking VR: Designing a Virtual Reality Experience for a Museum." *Proceedings of the 2018 Designing Interactive Systems Conference*, 805–815. Hong Kong, China: ACM Press.

Society for American Archaeology. 2019. "What is Archaeology?" Accessed June 2, 2019. https://www.saa.org/about-archaeology/what-is-archaeology.

Svensson, P. 2010. "The Landscape of Digital Humanities." *Digital Humanities Quarterly* 4, no. 1. Accessed June 2, 2019. http://www.digitalhumanities.org/dhq/vol/4/1/000080/000080.html.

Using AI for Cartographic Style Transfer

Song Gao *, Yuhao Kang

Geospatial Data Science Lab, Department of Geography, University of Wisconsin-Madison, Song Gao, song.gao@wisc.edu, Yuhao Kang, yuhao.kang@wisc.edu

* Corresponding author

Keywords: geospatial artificial intelligence, GeoAI, generative adversarial network, GAN, style transfer, map design

Abstract

The advancement of artificial intelligence (AI) technologies makes it possible to learn stylistic design criteria from existing maps or other visual art and transfer these styles to make new digital maps. In our recent work, we propose a novel framework using generative adversarial networks (GANs) for cartographic style transfer, that is, to adopt the appearance or visual style of another set of map tiles to render the input GIS data layers across multiple map scales. Our experiment results show that GANs have great potential for multiscale map style transferring, but many challenges remain, requiring future research.

Introduction

Recent advancements in artificial intelligence, especially deep learning, have revolutionized multiple domains in both scientific and practical ways (LeCun, Bengio, and Hinton 2015). Deep learning methods have enabled an automated capability for computers to learn hierarchical representational features and patterns from massive and complex data. The Geospatial Data Science Lab at the University of Wisconsin-Madison (GeoDS@UW) conducts cutting-edge research activities using various amounts of geospatial big data (Gao 2017) together with machine learning and deep learning methods toward the emerging field of geospatial artificial intelligence (GeoAI) for geographic knowledge discovery and decision support. In our recent work (Kang et al. 2019), we propose a novel framework using generative adversarial networks for cartographic style transfer, that is, to adopt the appearance or visual style of another set of map tiles to render the input map layers across multiple map scales. In this article, we briefly introduce this work, discuss main challenges, and share our vision for using state-of-the-art AI technologies in cartography and geographic information science (GIScience).

Experiment and Discussion

A map style is an aesthetically cohesive and distinct set of cartographic design characteristics (Kent and Vujakovic 2009). The map style sets the aesthetic tone of the map, evoking a visceral, emotional reaction from the audience based on the interplay of form, color, type, and texture (Buckley and Jenny 2012; Gao, Janowicz, and Zhang 2017). Increasingly, web cartographers need to develop a coherent and distinct map style that works consistently across multiple map scales to enable interactive panning and zooming of a "map of everywhere" (Roth, Brewer, and Stryker 2011). A number of web mapping services and technologies now exist to develop and render such multiscale map style rules as interlocking tilesets, such as CartoCSS and Mapbox Studio. Here, we ask if AI can help illuminate, transfer, and ultimately improve multiscale map styling for cartography, automating some of the multiscale map style re-creation and assisting the cartographer in developing novel representations. We utilize two GANs (i.e., Pix2Pix and CycleGAN) to transfer existing style criteria from Google Maps tiles and an artwork library by Claude Monet to new multiscale maps without the input of CartoCSS or other style configuration sheets. Figure 1 shows an example output of cartographic style transfer to raw GIS input data from the Google Maps style using GANs. The tilesets look realistic to the Google Maps style. In addition, GANs can approximate several map generalization operators (including enhancement, selection, and typify; see more discussions in Kang et al. 2019). From the qualitative visual analysis, several visual variables of the target styled maps are retained, including the feature color, the line width, and feature shape, especially in urban areas with buildings and roads. The locations of some point feature markers and text labels are also learned from the transfer styled maps. However, the GANs failed to apply legible textual labels from the target styled maps. More examples can be found in the publication (Kang et al. 2019). Although most of the generated maps look realistic, several problems and challenges remain. First, since most GANs are based on pixels from the input images, the topology of geographic features may not be well retained. Second, because of the existence of point markers and textual labels in the tiled maps, the quality of transfer styled maps is influenced by them. However, the point markers and textual labels are important to the map purpose and might require separate pattern recognition models to achieve better results.

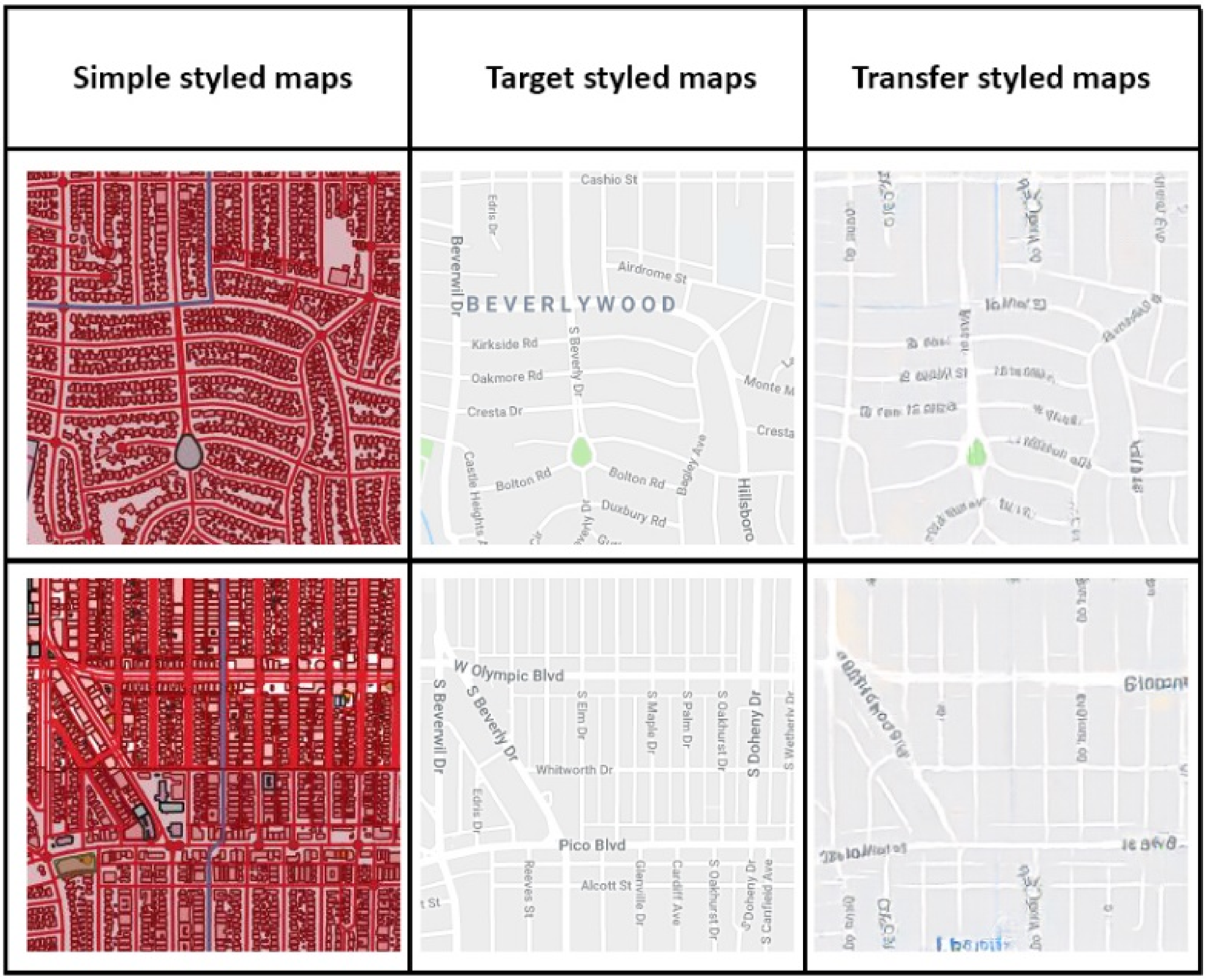


Figure 1. Results of cartographic style transfer to raw GIS input data from the Google Maps style using GANs.

Conclusion and Future Work

In sum, this research demonstrates substantial potential for implementing AI techniques for map style transferring and generalization in cartography. Here, we outline several important directions for the use of AI in cartography moving forward. First, our use of GANs can be extended to other mapping contexts such as to help cartographers deconstruct the most salient stylistic elements that constitute the unique look and feel of existing designs, using this information to improve designs in future iterations. This research also can help nonexperts who lack professional cartographic knowledge and experience to generate reasonable cartographic style sheet templates based on inspirational maps or visual art. Finally, integration of AI with cartographic design may automate part of the generalization process, a particularly promising avenue given the difficulty of updating high-resolution datasets and rendering new tilesets to support the map of everywhere.

Future developments should assess the uncertainty and reproducibility of outcomes using AI. Interpreting black box models requires the understanding of domain knowledge. The location uncertainty, topology, and spatial heterogeneity along with other characteristics in geospatial data make this issue more prominent when researchers apply AI techniques in cartography and GIScience. These characteristics make the training of AI models in geospatial studies more challenging and may require massive labeled data. However, recently, leading researchers in AI have stressed the need for a new theory for machine learning and deep learning, pointing out that the human brain learns without the need of all that labeled data to reach a conclusion (Hinton 2017). Future studies and developments are needed to address these concerns.

References

Buckley, A., and B. Jenny. 2012. Letter from the guest editors. *Cartographic Perspectives*, no. 73.

Gao, S. 2017. "Big Geo-Data." In *Encyclopedia of Big Data.* Eds L. A. Schintler and C. L. McNeely, *1–3*.

Gao, S., K. Janowicz, and D. Zhang. 2017. "Designing a map legend ontology for searching map content." *Advances in Ontology Design and Patterns* 32, 119–130.

Hinton, Geoffrey. 2017. "Artificial intelligence pioneer says we need to start over." *Axios*, September 15, 2017. https://www.axios.com/artificial-intelligence-pioneer-says-we-need-to-start-over-1513305524-f619efbd-9db0-4947-a9b2-7a4c310a28fe.html.

Kang, Y., S. Gao, and R. E. Roth. 2019. "Transferring Multiscale Map Styles Using Generative Adversarial Networks." *International Journal of Cartography.* doi: 10.1080/23729333.2019.1615729.

Kent, A. J., and P. Vujakovic. 2009. "Stylistic diversity in European state 1:50,000 topographic maps." *The Cartographic Journal* 46(3), 179–213.

LeCun, Y., Y. Bengio, and G. Hinton. 2015. "Deep learning." *Nature* 521(7553), 436.

Roth, R. E., C. A. Brewer, and M. S. Stryker. 2011. "A typology of operators for maintaining legible map designs at multiple scales." *Cartographic Perspectives* 68, 29–64.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

The Fusion of Remote Sensing and Social Sensing in Rapid Flood Mapping: Motivation, Opportunities, and Challenges

Xiao Huang

University of South Carolina, Columbia, SC, U.S, xh1@email.sc.edu

Keywords: Flood mapping, Social sensing, Remote sensing, Data fusion

Abstract

Remote sensing and social sensing have fundamentally facilitated flood mapping in many ways. Their intrinsic limitations, however, have greatly hampered their practicality when data from those two sources is utilized separately. The motivation for fusing remote sensing and social sensing relies on the assumption that they can compensate for each other's inherent limitations. Therefore, the fusion is expected to enable better situational awareness during or after a flood event by improving current flood mapping that relies on only a single data source. This article first introduces approaches to and advantages and limitations of remote sensing and social sensing in flood mapping. Then, the superiority of fusing information from the aforementioned two sources is illustrated in four aspects: the temporal dimension, the spatial dimension, credibility, and information richness. Finally, the opportunities and challenges of fusing remote-sensing and social-sensing data are listed and discussed. This article aims to draw attention to an emerging fusion-based flood mapping approach, and the topic discussed in this article is expected to seed a wide range of future studies for rapid and improved flood situational awareness.

Introduction to Remote Sensing and Social Sensing in Flood Fapping

Among all the flood-related damage mitigation activities, flood inundation mapping—hereafter referred to as flood mapping—is most critical for emergency response and postevent damage assessment. Flood mapping is able to provide situational awareness to the public and quickly draws attention to areas where immediate actions are needed. As it is often difficult and dangerous to conduct simultaneous field surveys during a disaster event, noncontact techniques have often been used to collect information and contribute to flood mapping. In general, the methods for current flood mapping studies can be broken into roughly two categories based on their data sources: remote sensing and social sensing.

Remote sensing has long been used to monitor flood inundation and its dynamics. Unlike field survey methods, remotely sensed images provide large spatial coverage and make near real-time flood monitoring possible. Optical remote sensing and microwave remote sensing are two commonly used techniques. Optical remote sensing makes use of visible, near-infrared, and short-wave infrared signatures from the ground to delineate flooded areas (Sanyal and Lu 2004). The greatest problem with optical remote sensing in flood mapping is its limited temporal resolution and the inability to acquire cloud-free imagery during extreme weather conditions. For these reasons, optical remote sensing usually fails to provide real-time flood assessment and is generally used to observe soil wetness days after a flood event. In comparison, microwave remote sensing—particularly radar imagery—largely overcomes the limitations caused by weather, as the radar pulse can easily penetrate cloud cover. However, the disadvantages of using imagery from radar sensors lie in the classification of messy signals resulting from complex ground and system variables, causing great challenges for accurate flood mapping, especially in urban areas (Smith 1997). In addition, similar to optical remote sensing, an almost inevitable observation lag usually happens due to the revisiting cycles of satellites.

Social sensing has gotten increasing attention due to the popularity of crowdsourcing approaches. Volunteered geographic information (VGI), a type of crowdsourcing data, provides an alternative approach to reporting information about a flood in real time. Defined by Goodchild (2007), VGI describes the concept of citizens as sensors, allowing rich volunteered information to be provided in the form of text, images, and videos to aid geospatial and temporal analysis during a flood event. With more open-source crowdsourcing platforms being built, there is an upsurging interest in utilizing VGI for getting better flood awareness (Fohringer et al. 2015; Huang et al. 2018a). Compared to traditional remote-sensing approaches, the largest advantage for social sensing in flood mapping is the timely situational awareness derived from a large number of contributors on the ground (Li et al. 2018). Its largest limitations, however, lie in its built-in assertiveness characteristic and the uncertainties introduced from the information source—that is, untrained VGI providers.

Motivation for Fusing Remote Sensing and Social Sensing

Remote sensing and social sensing have their own merits and drawbacks in assisting flood situational awareness (summarized in table 1). The motivation behind their fusion relies on the assumption that their fusion will lead to the reciprocal compensation for their intrinsic limitations (Huang et al. 2018b). The compensation for limitations lies in the following aspects:

- *Temporal dimension*—Due to the fixed nature of satellite revisiting cycles, remote-sensing imagery often fails to provide real-time observations. In addition, the remotely sensed observations only describe a snapshot of a flooding situation and lack temporal continuity. In contrast, social sensing documents flood awareness in a real-time manner, and the collected responses usually evolve over time. The fusion aims to solve the imagery lag problem, reconstruct the flooding situation at a given time, and provide flood situational awareness with temporal continuity.
- *Spatial dimension*—Despite the coarse resolution, satellite images render a synoptic view in a large geographic area and therefore contribute to a holistic understanding of flooding status. The large coverage by satellite observations compensates for the potentially limited social responses, especially in rural areas. Social responses, on the other hand, provide fine-scale ground observations, greatly improving the quality of flood mapping at a local level. The rich flood-related social responses in urban areas also lead to improved urban flood mapping.
- *Credibility*—Although socially sensed responses have real-time merit, their contributors are mainly untrained volunteers. In comparison, remotely sensed flood awareness based on satellite sensors is provided by an authoritative source that has high credibility. The fusion not only offers the real-time merit from social sensing but also enhances the credibility from remote sensing.
- *Information richness*—Remotely sensed observations only contain information that can be used to infer the ground wetness. Socially sensed responses, however, contain rich contextual information that can be used to conduct public-sentiment and damage assessments, acquire water height, dispatch first responders, and gauge evacuation status. The fusion of the two data sources largely contributes to the richness of information acquired during the flood event, thus benefiting a variety of flood mitigation approaches.

Table 1. Pros and cons in remote sensing and social sensing

	Remote sensing	Social sensing
Pros	• Large coverage • Authoritative information • Near real-time observations (days lag notwithstanding) • Accurate spatial information (georeferenced imagery)	• High temporal resolution (real-time responses from volunteers) • Rich contextual information, including flood extent, damage, evacuation status, water level, and public sentiment • Direct ground observation at a local level • Useful information extracted with no expertise required
Cons	• Limited spatial resolution • Limited temporal resolution • Lack of contextual information • Lack of situational awareness at a local level • Penetration problem (for optical remote sensing) and signal noises (for microwave remote sensing) • Requirement of expertise to extract useful information	• Small coverage, usually with several intrinsic biases (population bias, cultural bias, age bias, etc.) • Nonauthoritative information from untrained volunteers • Low data quality (unstructured, noisy, high level of uncertainty) • Vagueness of spatial information (varied accuracy of geocoding) • Huge data volume with only a small proportion useful for flood mapping

Opportunities and Challenges

While fusing remote sensing with social sensing can lead to improved flood monitoring, obstacles that prevent this fusion from being practical still exist. The opportunities and challenges of fusing remote sensing and social sensing lie in the following aspects:

- *Designing and comparing fusion approaches*—Data heterogeneity can pose great challenges to systematically fusing data from multiple modalities (Wang et al. 2018), especially for the two completely different types of observations to be fused: remote-sensing observation and social-sensing observations. Numerous attempts have been made, and their results seem promising. Schnebele and Cervone (2013) proved that remote sensing flood assessment can be improved by high temporal resolution VGI data. Huang et al. (2018a and 2018b) confirmed that satellite observations and social responses on the ground can, together, contribute to better flood awareness. More recently, Wang et al. (2018) designed a novel spatial density estimation method that combines imaging sensors and social media and concluded that their fusion leads to more robust flood estimation. These studies, however, applied completely different fusion mechanisms dependent upon their own assumptions. Thus, the need to cross-compare their approaches and benchmark their performances is urgent.

- *Creating an interactive web interface*—Real-time flood situational awareness is now at the forefront of rapid response and damage assessment. To promote real-time situational awareness to the public and to assist first responders for better decision-making, there is great need for an interactive web interface that contains, showcases, and analyzes multiple sensing modalities. The interface should have the ability to self-update and address the continuous input of socially sensed information as well as the temporal-discrete remotely sensed images. The envisioned interface should provide uninterrupted situational awareness that benefits local authorities.
- *Integrating cross-sensor satellite observations*—Satellite observation during a flood event is temporally discrete. An integrative approach is needed when multiple, usually cross-sensor satellite observations are available. The combination of multisensor data—for example, optical sensors and microwave sensors—can be critical to address the need for data acquisition for all time and all weather conditions during the flood event (Khan et al. 2014). The integration of cross-sensor observations should be conducted before fusion with social sensing data.
- *Extracting useful flood-related social responses in an automatic manner*—Extracting useful information from social media remains a challenge, as the data is often noisy, unreliable, heterogeneous, and massive (Huang et al. 2018c). Current approaches to collecting useful social responses for flood mapping are mainly manual and involve intensive labor. Given the fact that social responses during a flood event usually come in continuous streams, the automation of extracting flood-related social responses can make uninterrupted flood monitoring possible. Thanks to the advancement of deep learning (LeCun et al. 2015), approaches have been designed to retrieve massive flood-related social responses in an automated manner (Huang et al. 2018c, Feng and Sester 2018).
- *Linking contextual information with flood maps*—Transcending traditional flood maps that only present inundation extent or inundation probability, the additional contextual information from social-sensing data potentially contributes to a wide range of studies that are not possible solely relying on the spatial information (Sit et al. 2019). The rich contextual information (e.g., water height, damages, casualties, traffic conditions, public sentiment) documented in the massive social responses needs to be considered to provide contextually enhanced flood situational awareness in a real-time manner.

Conclusions

The rise of VGI platforms, such as social media—coupled with the emergence of big earth data—creates a golden opportunity for cartographers to renovate traditional flood mapping techniques that tend to rely heavily on a single data source. In light of the intrinsic limitations of remote sensing and social sensing, their fusion is expected to be beneficial to the acquisition of improved situational awareness by resolving those limitations. This fusion contributes to a better understanding of the flood situation with improved temporal contiguity, extended spatial coverage, enhanced credibility, and enriched contextual information. By designing advanced fusion algorithms, benchmarking model performance, developing an interactive web interface, automating the retrieval of social responses, and linking contextual information with flooding status, cartographers can provide improved flood awareness rapidly, largely benefiting local authorities for better decision-making during and after flood events.

References

Feng, Yu, and Monika Sester. 2018. "Extraction of Pluvial Flood Relevant Volunteered Geographic Information (VGI) by Deep Learning from User Generated Texts and Photos." *ISPRS International Journal of Geo-Information* 7, no. 2: 39.

Fohringer, J., D. Dransch, H. Kreibich, and K. Schröter. 2015. "Social Media as an Information Source for Rapid Flood Inundation Mapping." *Natural Hazards and Earth System Sciences* 15, no. 12: 2725–2738.

Goodchild, Michael F. 2007. "Citizens as Sensors: The World of Volunteered Geography." *GeoJournal* 69, no. 4: 211–221.

Huang, Xiao, Cuizhen Wang, and Zhenlong Li. 2018b. "Reconstructing Flood Inundation Probability by Enhancing Near Real-Time Imagery with Real-Time Gauges and Tweets." *IEEE Transactions on Geoscience and Remote Sensing* 56, no. 8: 4691–4701.

Huang, Xiao, Cuizhen Wang, and Zhenlong Li. 2018a. "A Near Real-Time Flood-Mapping Approach by Integrating Social Media and Post-Event Satellite Imagery." *Annals of GIS* 24, no. 2: 113–123.

Huang, Xiao, Cuizhen Wang, Zhenlong Li, and Huan Ning. 2018c. "A Visual–Textual Fused Approach to Automated Tagging of Flood-Related Tweets during a Flood Event." *International Journal of Digital Earth*. doi:10.1080/17538947.2018.1523956.

Khan, Sadiq, Yang Hong, Jonathan Gourley, Muhammad Khattak, and Tom De Groeve. 2014. "Multi-Sensor Imaging and Space-Ground Cross-Validation for 2010 Flood along Indus River, Pakistan." *Remote Sensing* 6, no. 3: 2393–2407.

LeCun, Yann, Yoshua Bengio, and Geoffrey Hinton. "Deep Learning." 2015. *Nature* 521, no. 7553: 436.

Li, Zhenlong, Cuizhen Wang, Christopher T. Emrich, and Diansheng Guo. 2018. "A Novel Approach to Leveraging Social Media for Rapid Flood Mapping: A Case Study of the 2015 South Carolina Floods." *Cartography and Geographic Information Science* 45, no. 2: 97–110.

Sanyal, Joy, and X. X. Lu. 2004. "Application of Remote Sensing in Flood Management with Special Reference to Monsoon Asia: A Review." *Natural Hazards* 33, no. 2: 283–301.

Schnebele, E., and G. Cervone. 2013. "Improving Remote Sensing Flood Assessment Using Volunteered Geographical Data." *Natural Hazards and Earth System Sciences* 13, 669–677. doi:10.5194/nhess-13-669-2013.

Sit, Muhammed Ali, Caglar Koylu, and Ibrahim Demir. 2019. "Identifying Disaster-Related Tweets and Their Semantic, Spatial and Temporal Context Using Deep Learning, Natural Language Processing and Spatial Analysis: A Case Study of Hurricane Irma." *International Journal of Digital Earth*. doi: 10.1080/17538947.2018.1563219.

Smith, Laurence C. "Satellite Remote Sensing of River Inundation Area, Stage, and Discharge: A Review." 1997. *Hydrological Processes* 11, no. 10: 1427–1439.

Wang, Han, Erik Skau, Hamid Krim, and Guido Cervone. 2018. "Fusing Heterogeneous Data: A Case for Remote Sensing and Social Media." *IEEE Transactions on Geoscience and Remote Sensing* 99: 1–13.

International Cartographic Association
Association Cartographique Internationale
Cartography and Geographic Information Society

Learning about and Working with Map Projections

Fritz C. Kessler

Pennsylvania State University, fck2@psu.edu

Keywords: Map projection, Cartographic education, Coordinate systems

Abstract

Learning about and working with map projections can be a daunting task. This challenge stems from three sources. First, many students who learn about projections do so from general cartography textbooks. While these texts perform reasonably well at presenting basic projection knowledge, they do not explain how to select and tailor projections for a map. Second, technology has advanced considerably since the early 20th century, when projections were laboriously drawn by hand. Advances such as programming languages now allow mapmakers to automatically select from hundreds of projections for a map. Yet guidance on selecting a specific projection is missing. Third, working with projections in software requires that the user be able to define the associated projection parameters (e.g. choosing standard parallels). Assistance on specifying appropriate parameter values is absent. This short paper reviews recent research that examines learning about and working with projections.

Introduction

This paper discusses recent research activities whose focus is learning about and working with map projections. Kessler (2018) conducted a content analysis of general cartography textbooks to determine if developments in the projection field were being integrated into the material that students learn about projections. The content analysis specifically addressed whether developments in the projection field throughout the 20th and early 21st centuries that were important for students to learn were included in general cartography textbooks. In another paper, Kessler et al. (2017) summarized how the Internet has enabled projections to become more accessible and engaging. Some of these impacts include the web Mercator projection, online projection software (e.g. Flex Projector, www.flexprojector.com), and code libraries (e.g. PROJ.4). Collectively, these and other technological developments have helped bring the richness and awareness of projections to many mapmakers and map readers. Despite this richness and awareness, Kessler and Battersby (2019) pointed out that mapmakers still struggle when working with projections. Their recent work, *Working with Map Projections: A Guide to Their Selection*, fills this void by presenting new ideas on working with projections.

Learning about Map Projections

The field of map projections regularly sees developments occur (e.g. deriving a new projection). It would seem reasonable to expect that those developments that are important from a teaching standpoint would be included in cartography textbooks. Kessler (2018) examined whether projection material presented in cartography textbooks is keeping pace with developments in the field and whether that material is important for cartography students to learn. To perform the assessment, a content analysis was conducted of projection material discussed in 24 cartography textbooks published during the 20th and early 21st centuries. Results suggest that some material, such as projection properties, was discussed in all textbooks surveyed. Other material, such as methods used to illustrate distortion patterns and the importance of datums, was either inconsistently presented or rarely mentioned. Comparing recent developments in the field to the results of the content analysis, four recommendations are offered that future cartography textbooks should adopt when considering what projection material is important from a learning standpoint.

To begin, textbooks should discuss the importance that defining a coordinate system has in mapping software. For example, this definition must include a datum and a projection if appropriate. The results showed that only 18 percent of the textbooks in the early 20th century included references to components of a datum (e.g. reference ellipsoid), but this increased to 75 percent in the early part of the 21st century. Second, textbooks should summarize the results from experimental studies that provide insight into how map readers understand projection distortion, which can impact the selection of an appropriate projection. For example, Battersby and Kessler (2012) examined the cues that map readers use when perceiving distortion across a map's surface, while Šavrič et al. (2016) surveyed map readers' preferences for world projections. Textbooks varied considerably in their discussion of distortion and in the visualization methods used to illustrate it. Third, textbooks should review how projections have been impacted by technology, such as the Internet. The web Mercator projection has been particularly impactful as a de facto projection for most mapping services, yet it was not discussed in any of the textbooks. In response to criticism levied against this projection (Battersby et al. 2014), alternative approaches that use different projections depending on the map scale, such as Adaptive Composite Map

Projections (Jenny et al. 2013), have been proposed. Recently, Google Maps has moved away from sole reliance on the web Mercator and incorporates the vertical perspective azimuthal projection for the smaller scale zoom levels (Liptak 2018). Finally, people who work with projections include web map application developers, GIS analysts/technicians, and citizen mapmakers. Their unique workflows demand different kinds of projection knowledge, and textbooks should parse the projection material accordingly so that contemporary mapmakers can be better equipped to carry out specialized work with projections.

Working with Map Projections

Most projection selection guidelines are based on the generalization that specific map types (thematic) are best represented by a property (equal area) or that a projection class (cylindrical) is better suited for specific regions (the equator). While there is some truth to these statements, not all thematic maps depend on equal area considerations nor should a cylindrical projection be automatically chosen for equatorial-centered maps. For example, isarithmic maps use spatial interpolation methods to generate surfaces based on distance measurements. Projections, in general, and equal area projections, specifically, limit the accuracy of distance measurements.

Kessler and Battersby (2019) presented a new approach to working with and selecting projections. In developing a different approach to selecting a projection, the authors recognized that traditional projection selection guidelines required the mapmaker to have a working knowledge of projections. Since mapmakers' knowledge of projections is generally limited, the authors felt that mapmakers are more likely to know something about their data, the intended symbolization method, and the map's purpose. These ideas serve as the foundation of the authors' holistic approach to selecting a projection.

To start, the mapmaker should understand how the phenomena are spatially modeled. The authors adopted MacEachren and DiBiase's (1991) conceptual model of geographic phenomenon (fig. 1). The authors felt that such familiarity with how the phenomenon was distributed across the earth's surface helps the mapmaker conceptualize the phenomenon according to the intended symbolization method used to represent the data. For example, the distribution of the acres of harvested timber could be conceptualized as discrete and smooth. For this data, using the dot symbolization method would be appropriate. The dot method requires an equal area projection, since the size of the enumeration unit is the container for the dots. However, mapping the distribution of a migration would be matched well with proportional flow lines, which do not require adherence to the equal area property. In fact, the overall spatial pattern of flow lines can be greatly enhanced by an appropriately chosen projection (fig. 2A). Projections can also hinder the readability of the spatial pattern of the flow lines. Figure 2B shows several "broken" flow lines due to the misuse of an interrupted projection.

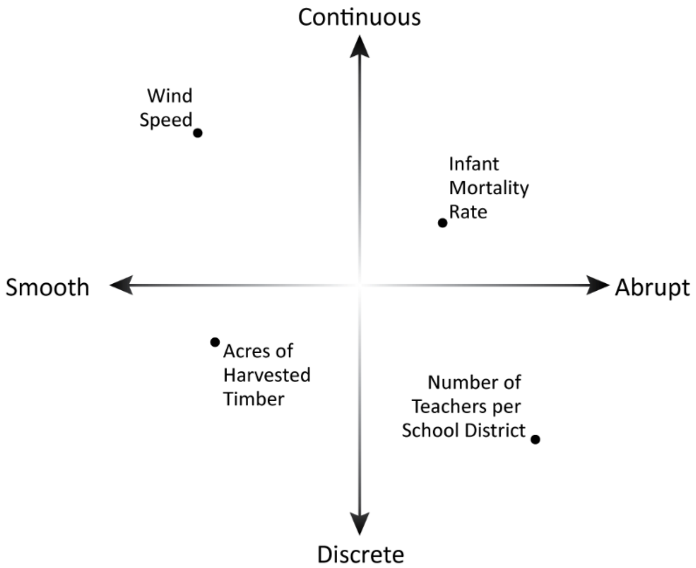


Figure 1. MacEachren and DiBiase's (1991) conceptual model of geographic phenomena.

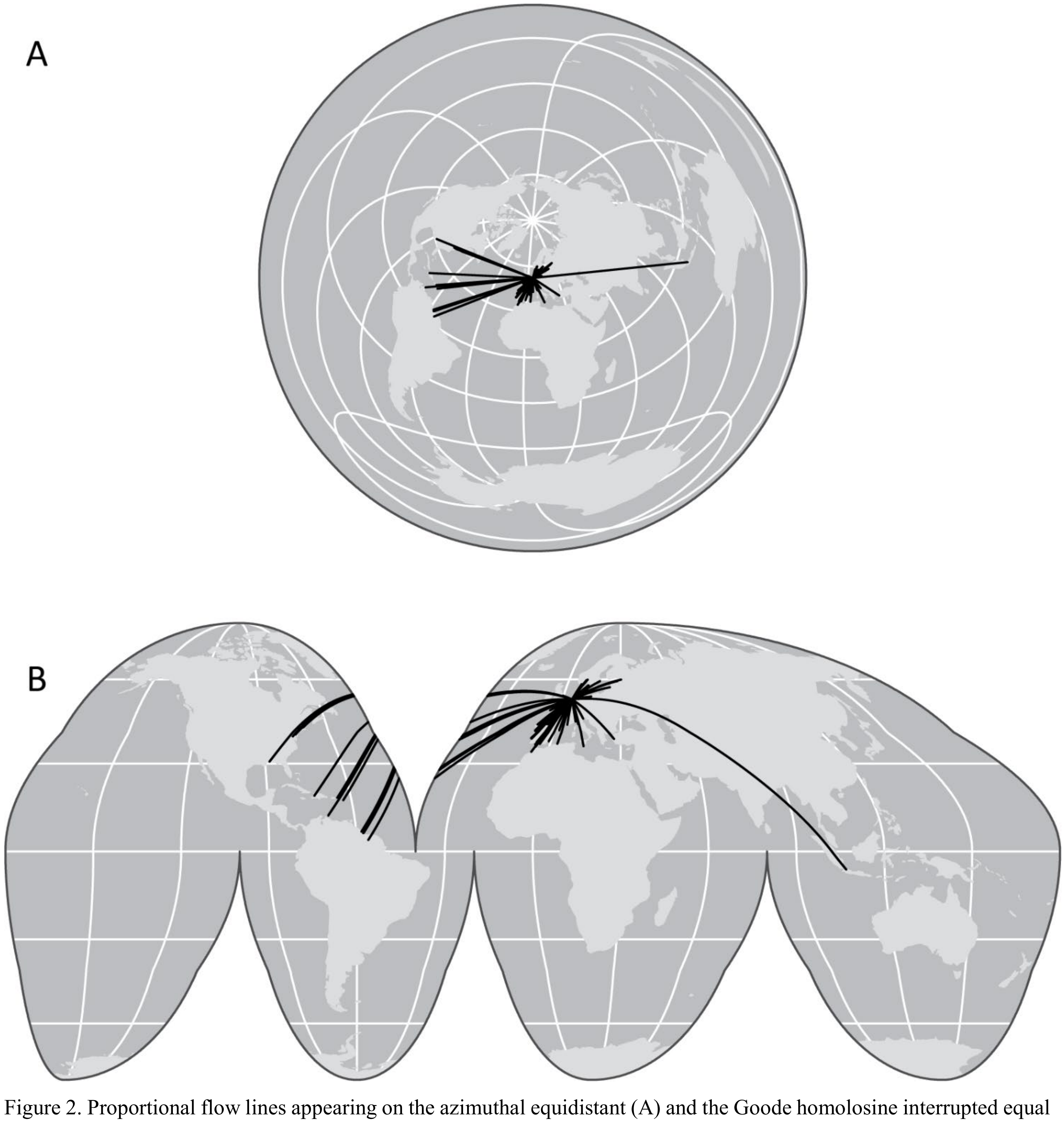


Figure 2. Proportional flow lines appearing on the azimuthal equidistant (A) and the Goode homolosine interrupted equal area (B) projections.

The authors also pointed out that when selecting projections, the mapmaker should account for the intended visual analysis task(s) and be aware of any associated limitations that a projection presents. For example, projections generally have greater levels of distortion at the periphery of the map, which is very noticeable on global scale maps. When mapping isolines, for instance, high levels of distortion that are located near the periphery of some projections often compress isolines to the point of being unreadable. Figure 3A shows global sea surface temperatures represented by isotherms on the Lambert cylindrical equal area projection. On this projection, landmasses and the spacing of lines of latitude are compressed in the polar areas more than at the equator. This compression makes distinguishing the isotherms at higher latitudes difficult. Figure 3B shows the same dataset mapped using the Eckert III compromise pseudocylindrical projection. On this projection, the landmasses and the lines of latitude are equally spaced along a line of longitude as seen in figure 3A. This is an important factor when representing the isotherms, especially when considering how temperature changes with latitude. The temperature gradient (represented by the spacing between the isotherms) shown in figure 3B is better reflective of the equal spacing as it occurs on the earth. If the mapped dataset varies by latitude (as temperatures generally do), parallels of latitude should appear equally or nearly equally spaced (shown in figure 3), which may offer advantages to the map reader in visualizing the data and relating the phenomena to changes in latitude.

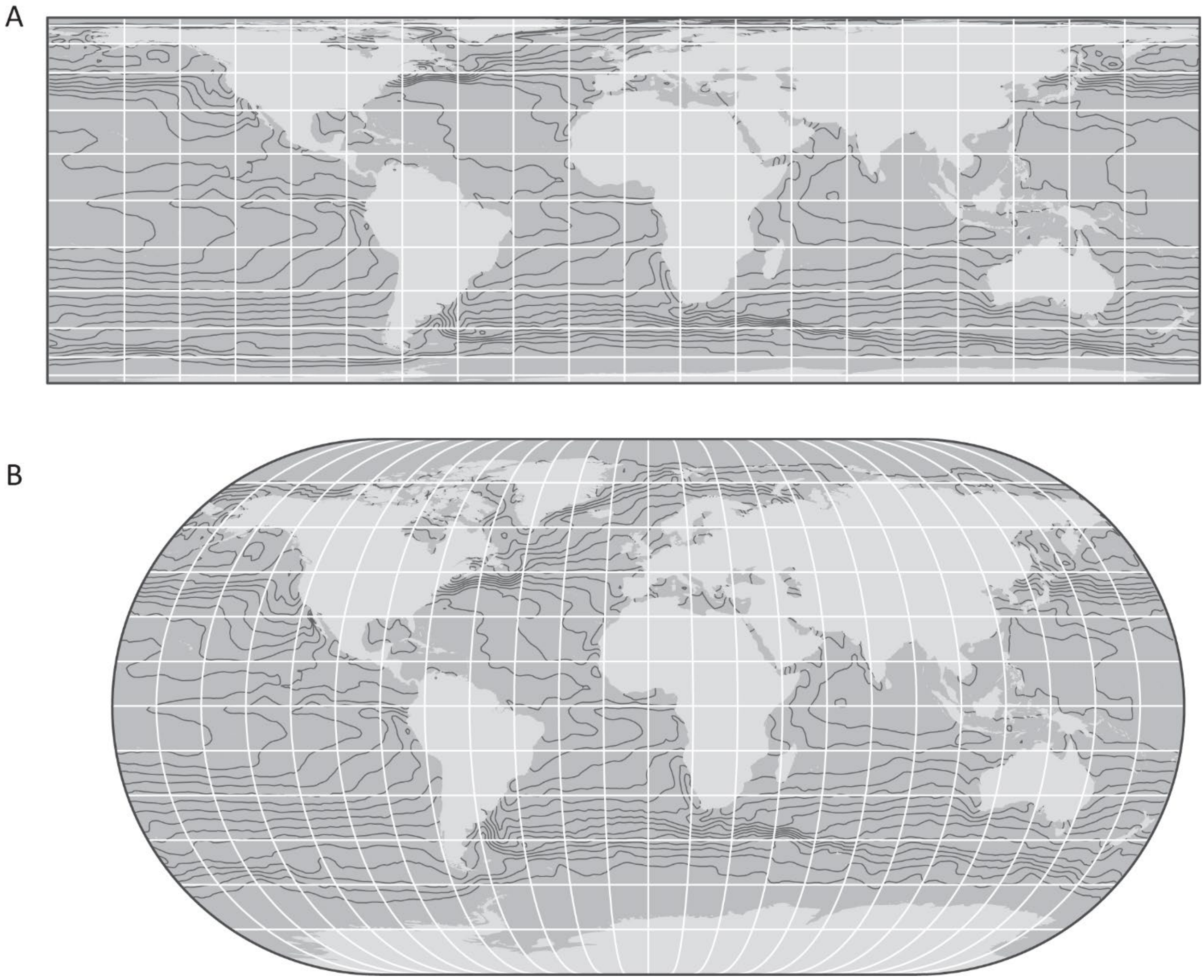


Figure 3. A map of global sea surface temperature (SST) isotherms cast on the Lambert cylindrical equal area (A) and Eckert III pseudocylindrical compromise (B) projections.

The authors additionally included broader map design and analytic considerations for selecting a projection. These considerations included the projection shape, arrangement of the graticule, appearance of the poles, and interpretability. Projections come in different shapes (e.g. rectangles, ovals, circles, and cones), and this shape can be considered a variable in the overall map design. For example, rectangular-shaped projections fit a computer screen better than, for example, global scale, circle-shaped projections (e.g. azimuthal class). The graticule arrangement should serve as a mental frame of reference helping the map reader orient the map. The appearance of the poles can impact the readability of the landmasses and symbolization methods, especially near the map's periphery. Poles represented as points tend to compress landmasses and symbolization methods in the polar areas. Projections with poles represented as lines do not suffer from the extreme compression that is found with poles represented with points. Interpretability refers to the display of spatial patterns across global-scale maps. Interrupted projections (e.g. Goode homolosine) combined with symbolization methods that "extend beyond" the map's periphery can produce difficulties for some visual tasks.

Conclusion

Learning about and working with projections remains challenging to many mapmakers. This paper discussed recent research on these two challenges and offered suggestions on how to improve learning about and working with projections. While general cartography textbooks do a reasonable job of including foundational projection material, developments in the map projection field are generally not included. This lack of inclusion is more noticeable given the ongoing developments in technology and their impact on projections. Material discussing the importance of developments in defining a datum and projection, how projections have been integrated into the Internet, projections, and explaining the utility of code libraries was absent from recently published cartography textbooks. Mapmakers who work with projections need a set of guidelines to assist in selecting a projection. Existing guidelines do not necessarily lead to the recommendation of an appropriate projection, nor do they explain the logic of why one projection was selected over another. The authors suggest that a better approach to selecting a projection should focus more on the data, symbolization methods, and visual tasks associated with the map user. In addition, the projection shape, graticule arrangement, appearance of the poles, and interpretability should also be considered as design elements in selecting a projection.

References

Battersby, S. E., M. P. Finn, E. L. Usery, and K. H. Yamamoto. 2014. "Implications of web Mercator and its use in online mapping." *Cartographica: The International Journal for Geographic Information and Geovisualization* 49, no. 2: 85–101.

Battersby, S., and F. Kessler. 2012. "Cues for interpreting distortion in map projections." *Journal of Geography* 111, no. 3: 93–101.

Jenny, B., T. Patterson, and L. Hurni. 2008. "Flex Projector—interactive software for designing world map projections." *Cartographic Perspectives* 59: 12–27.

Kessler, F. 2018. "Map Projection Education in General Cartography Textbooks: A Content Analysis." *Cartographic Perspectives* 90: 6–30.

Kessler, F., and S. Battersby. 2019. *Working with Map Projections: A Guide to Their Selection*, Boca Raton: CRC Press.

Kessler, Fritz, S. Battersby, M. Finn, and K. Clarke. 2017. "Map Projections and the Internet." In *Choosing a Map Projection*, edited by Miljenko Lapaine and E. Lynn Usery, 117–148. New York: Springer.

Liptak, A. 2018. "Google Maps now depicts the Earth as a globe." *The Verge*, August 5, 2018. https://www.theverge.com/2018/8/5/17653122/google-maps-update-mercator-projection-earth-isnt-flat.

MacEachren, A., and D. DiBiase. 1991. "Animated maps of aggregate data: Conceptual and practical problems." *Cartography and Geographic Information Systems* 18, no. 4: 221–229.

Šavrič, B., B. Jenny, D. White, and D. Strebe. 2015. "User preferences for world map projections." *Cartography and Geographic Information Science* 42, no. 5: 398–409.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

The Cartogram Studio Project

Barry J. Kronenfeld

Eastern Illinois University, bjkronenfeld@eiu.edu

Keywords: Cartograms, Value-by-area maps, Density-equalizing maps, Population mapping

Abstract

The Cartogram Studio project aims to develop user-friendly software for manual construction of continuous cartograms. The project is built on the principle that algorithms should automate low-level operations while leaving control of high-level design choices in the hands of the human cartographer. Core elements of the project include (a) a joint triangulation framework to define a continuous transformation and facilitate the detection and avoidance of topological errors, (b) local adjustment tools to facilitate molding and shaping of regions, (c) real-time feedback on size targets, and (d) area-preserving simplification and smoothing operations to maintain line integrity.

Introduction

Population cartograms have piqued the interest of geographers for over a century due to their unique portrayal of a human cartography based on population rather than land area (Dorling and Ballas 2011). Raisz (1936, 295) argued that cartograms "set right common misconceptions held by even well-informed people." Most interest among cartographers has focused on continuous value-by-area cartograms in which the areal extent is in proportion to some measured value, and evidence suggests that these are indeed the most effective at communicating geographic data (Nusrat, Alam, and Kobourov 2017; but see Reyes and Juhasz 2015). The most popular algorithm for producing cartograms today is the diffusion algorithm (Gastner and Newman 2004).

Tobler (2004) noted that an infinite variety of continuous cartograms are possible for any given population dataset. Given the unexplored possibilities, there is no reason to believe that current algorithms produce the most effective cartograms (Woodruff 2008). While better and more efficient algorithms have greatly improved the ease with which cartograms can be constructed, the cognitive demands of this unique map form beg for greater artistic control. What would cartograms look like if their form were sculpted by a competent cartographer? We have some inkling of the possibilities from early hand-drawn cartograms (Kronenfeld 2018) and the recent proliferation of block cartograms on the Internet (Miller 2016). However, block cartograms are—well, blocky, and they are not quite comparable to truly continuous cartograms.

The purpose of the Cartogram Studio project is to develop an interactive software environment for constructing continuous cartograms. The project has been developed in Microsoft's .NET languages (Visual Basic, C#) using the DotSpatial open source geographic information system (GIS) library. This report documents development of the project since its inception.

Background

The first implementation of Cartogram Studio was for a conference poster (Kronenfeld 2014), and the initial framework was refined and described in Kronenfeld (2018). It involved a set of transformation tools to make local adjustments to size and shape, symbology and information feedback to track size errors, and a joint triangulation to maintain topological relations. While some form of tessellation has been used in other algorithms (e.g., Gastner and Newman 2004), a key insight of this work was that size objectives were achieved more quickly by deforming the triangulation on the source map rather than on the cartogram.

While the initial research demonstrated the ability to finely control cartogram form within a user interface environment, the initial framework was very cumbersome for two reasons. First, deforming the triangulation on the source map was counterintuitive, as triangle vertices had to be moved opposite to the desired direction of adjustment of polygon borders. Second, the strict prohibition of moves that created topological errors led to many moves being disallowed, especially as numerous local adjustments were chained together. As a result of these problems, cartogram construction was very slow, with example cartograms of US states and Chinese provinces taking numerous hours to produce.

Recent Improvements

Several improvements to the Cartogram Studio framework have been implemented since the publication of the Kronenfeld paper of 2018. Two major improvements are described here. First, the joint triangulation is now created from an adaptive triangulation of the population polygons (fig. 1). Specifically, the triangulation is constructed by (a) creating a constrained Delaunay triangulation of the population polygon vertices, (b) buffering the triangulation with three layers of added points, and (c) inserting triangle vertices at the midpoints of edges that are not on the polygon boundaries. To employ this new framework, it is necessary to first simplify the source polygons to reduce the number of vertices. This is well worth the effort, though, as it allows fast expansion of small regions while making the process of cartogram design much smoother and more intuitive.

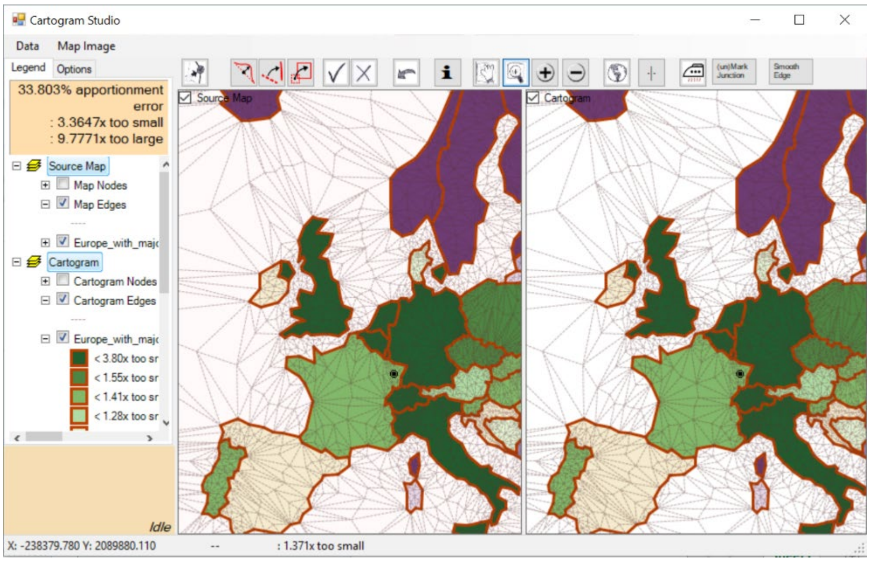
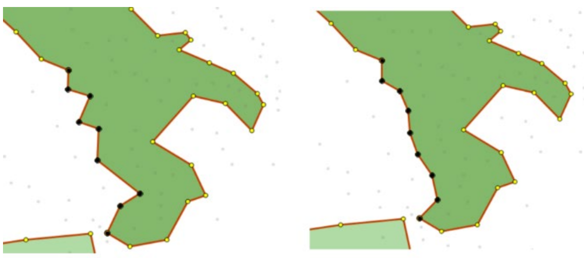


Figure 1. Current version of Cartogram Studio, with adaptive mesh to fit population polygons.

A second improvement has been to introduce a tool for smoothing polygon vertices (fig. 2). Through the successive application of local deformation operations, there is a tendency for borders to become jagged and for vertices to bunch together (fig. 2[a]). This leads to poor shape characteristics as well as topological errors. By applying area-preserving smoothing operations (e.g., Tutić and Lapaine 2010), it is possible to temper this process (fig. 2[b]).



(a) (b)

Figure 2. Application of a tool for automatically smoothing polygon vertices while preserving area. Figure shows a section of the Italian coastline after some local adjustments had created an unnatural jagged appearance: (a) before applying the smoothing tool and (b) after applying the smoothing tool.

Utilization

For several years, Cartogram Studio has been used annually in an undergraduate classroom exercise at Eastern Illinois University in cooperation with Dr. David Viertel. After a lecture outlining the purpose and history of cartograms, a quick demonstration of Cartogram Studio is provided. Students are then given approximately two hours of in-class laboratory time to construct a cartogram using data such as US states with population. While institutional review board approval has been obtained to study the students' interaction with the software, results have not yet been compiled. In general, students have shown a combination of eagerness and frustration, and feedback from students has been instrumental to improving the functionality and user interface. Recently a team of graduate students used Cartogram Studio to develop a framework for visualizing partisan bias in the outcomes of US congressional elections in several states (Kronenfeld et al. 2019).

An example of a cartogram produced using Cartogram Studio is shown in figure 3. Cartogram Studio software and other examples of cartograms produced by the author can be found on the project website (http://castle.eiu.edu/~bjkronenfeld/cartogramstudio.html).

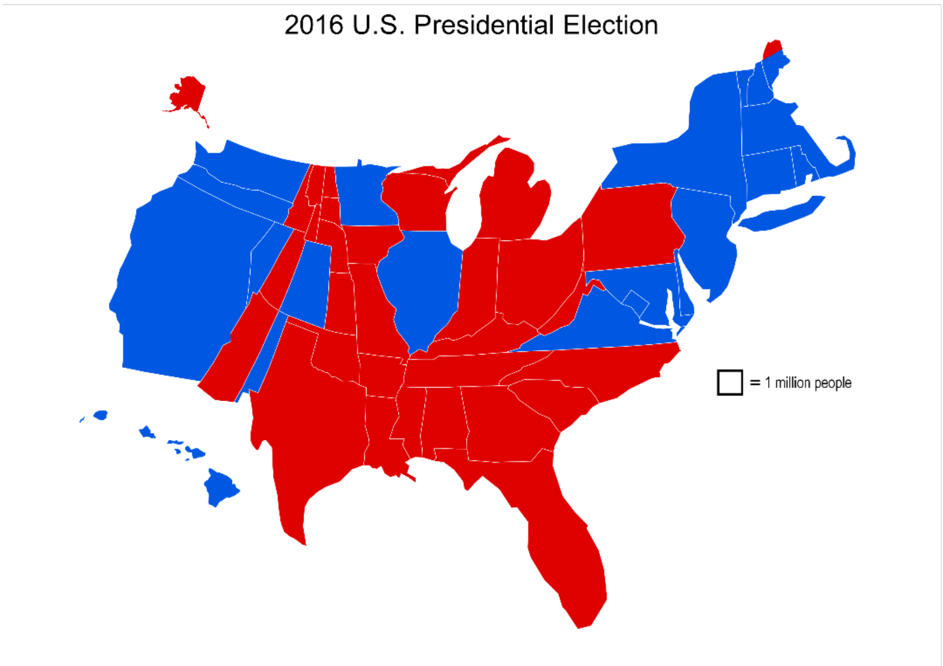


Figure 3. Cartogram of electoral college representation for US states in the 2016 presidential election, created in Cartogram Studio by the author.

Future Work

Much work remains to realize the objective of creating an intuitive and user-friendly environment for cartogram construction. Future research may focus on several areas. First, work is needed to develop the visual and symbolic language of local adjustment. The current version of Cartogram Studio has three adjustment tools: "Nudge, Line Adjustment, and Rectangle Adjustment". The question is this: what are other natural concepts that cartographic designers would employ to define individual adjustments and combinations of adjustments to transform a map into a cartogram? A second area of research relates to the preservation of topology and automated adjustment of the triangulation. When higher-level adjustment tools are employed that simultaneously move multiple vertices, it is inevitable that a user-defined adjustment will sometimes alter topological relations of the underlying data. While the current version of Cartogram Studio can prevent such adjustments from taking place, it can be frustrating for a user to determine what vertex or set of vertices is preventing the desired adjustment. In such cases, it would be ideal for the software to automatically search for a way to minimally alter the user-defined adjustment to avoid the introduction of topological errors. Funding is being sought to develop these and many other minor and major improvements. Ultimately, it would be desirable to port the framework to HTML and JavaScript for greater accessibility.

References

Dorling, Danny and Dimitris Ballas. 2011. "Innovative Ways of Mapping Data about Places." In *Understanding Social Research: Thinking Creatively about Method*, edited by J. Mason and A. Dale, 150–164. London: Sage.

Gastner, Michael and Mark Newman. 2004. "Diffusion-Based Method for Producing Density-Equalizing Maps." *Proceedings of the National Academy of Sciences* 101, 20: 7499–7504.

Kronenfeld, Barry. 2014. "Cartogram Construction from Dot Density Maps Using Triangular Mesh Transformation." Poster abstract, presented at the Association of American Geographers Annual Meeting, April 9, Tampa, FL.

Kronenfeld, Barry. 2018. "Manual Construction of Continuous Cartograms through Mesh Transformation." *Cartography and Geographic Information Science* 45, 1: 76–94.

Kronenfeld, Barry, Bolarinwa Oladipupo, Agenda Nawa, Raju Thupran, and David Viertel. 2019. "Towards an Atlas of Gerrymandering." Poster submitted in presented at the 2019 Avenza Map Competition. https://pen.eiu.edu/~boladipupo/Gerrymandering.html.

Miller, Greg. October 12, 2016. "Election Maps Can Be Misleading—Here's a Solution." *National Geographic*. https://news.nationalgeographic.com/2016/10/improved-election-map-cartograms/.

Nusrat, Sabrina, Jawaherul Alam and Stephen Kobourov. 2017. "Evaluating Cartogram Effectiveness." *IEEE Transactions in Visualization and Computer Graphics* 24, 2: 1077–1090.

Raisz, Edwin. 1934. "The Rectangular Statistical Cartogram." *Geographical Review* 24, 2: 292–296.

Reyes Nuñez, José Jesús, and Barbara Juhász. 2015. "Hungarian Survey on the Use of Cartograms in School Cartography." *International Journal of Cartography* 1, 1: 5–17.

Sun, Shipeng. 2013. "A Fast, Free-Form Rubber-Sheet Algorithm for Contiguous Area Cartograms." *International Journal of Geographical Information Science* 27, 3: 567–593.

Tobler, Waldo. 2004. "Thirty Five Years of Computer Cartograms." *Annals of the Association of American Geographers* 94, 1: 58–73.

Tutić, Dražen, and Miljenko Lapaine. 2010. "New Method for Reducing Sharp Corners in Cartographic Lines with Area Preservation Property." In *Proceedings of the 14th International Conference on Geometry and Graphics: August 5th–9th, 2010, Kyōto, Japan*, Naomi, A., K. Takashi, M. Jun, S. Aya, and Y. Yasuishi, (eds.), 289–290.

Woodruff, Andy. November 4, 2008. "I Hate Your Favorite Election Map." *Andy Woodruff* (blog). http://andywoodruff.com/blog/i-hate-your-favorite-election-map/.

International Cartographic Association
Association Cartographique Internationale
Cartography and Geographic Information Society
CaGIS

Enabling the Spatial Discovery of Research Data in Libraries

Sara Lafia *, Werner Kuhn

University of California, Santa Barbara, Department of Geography, Sara Lafia, slafia@ucsb.edu, Werner Kuhn, werner@ucsb.edu

* Corresponding author

Keywords: information discovery, spatialization, digital libraries, spatial data portals, Semantic Web

Abstract

The Department of Geography at the University of California, Santa Barbara (UCSB), in partnership with the UCSB Library and Esri, has studied the opportunities to spatially enable the discovery of research data in a library setting. It has developed strategies that use location to integrate research data from diverse campus departments like Marine Biology, Archaeology, and Political Science in a web-based geographic information system (GIS) platform. A protocol for spatially enabling metadata links the research data to associated publications, references them by the geographic location of their contents, and assigns them locations in abstract thematic spaces. This work has resulted in an open portal of campus research, supporting the spatial discovery of data and publications through a world map, a spatialized topic map, and a network of thematically related research. The outlook for the spatial discovery of research data at UCSB and any other library foresees improving researchers' understanding of what places and themes the research data is about.

Putting University Research on the Map

In the 1990s, UCSB established and advanced the vision for a spatially enabled digital library through the Alexandria Digital Library project, providing access to diverse materials with functionality for spatiotemporal search. Starting in 2015, a team of researchers under the direction of Professor Werner Kuhn, supported by the UCSB Library, the Center for Spatial Studies, and the Spatial Discovery Fund, revived and vastly expanded this vision by making research datasets and publications spatially discoverable. Diverse materials, ranging from imagery and scanned environmental impact reports to dynamic citizen science data, have been made available through a geographically enabled search interface: UCSB's open data site, supported by ArcGIS Online. Since the launch of UCSB's site, over 160 datasets have been exposed, including layers from the university's Interactive Campus Map, along with feature services, reports, and imagery used by campus researchers. These datasets have also been used to build applications, like a Campus Bicycle Feedback service to collect volunteered geographic information (VGI).

The UCSB open data site bridges disciplines by identifying areas of the world for which research data are available, regardless of discipline or format. Research data are too often siloed by discipline or by theme (Mayernik et al. 2012), whereas the spatial organization of research cuts across discipline and format, offering interdisciplinary views and promoting collaboration. For example, campus researchers from several departments work in the Mesoamerican region, yet data about archaeological excavations, contested political borders, and land-cover types have not been discoverable in one place until recently (fig. 1). Datasets that overlap in their geographic extents are now discoverable, which encourages data sharing and linking across disciplines. Relevant publications or other documents that reference the datasets are linked to them, providing additional context that aids in their discovery (Lafia et al. 2016).

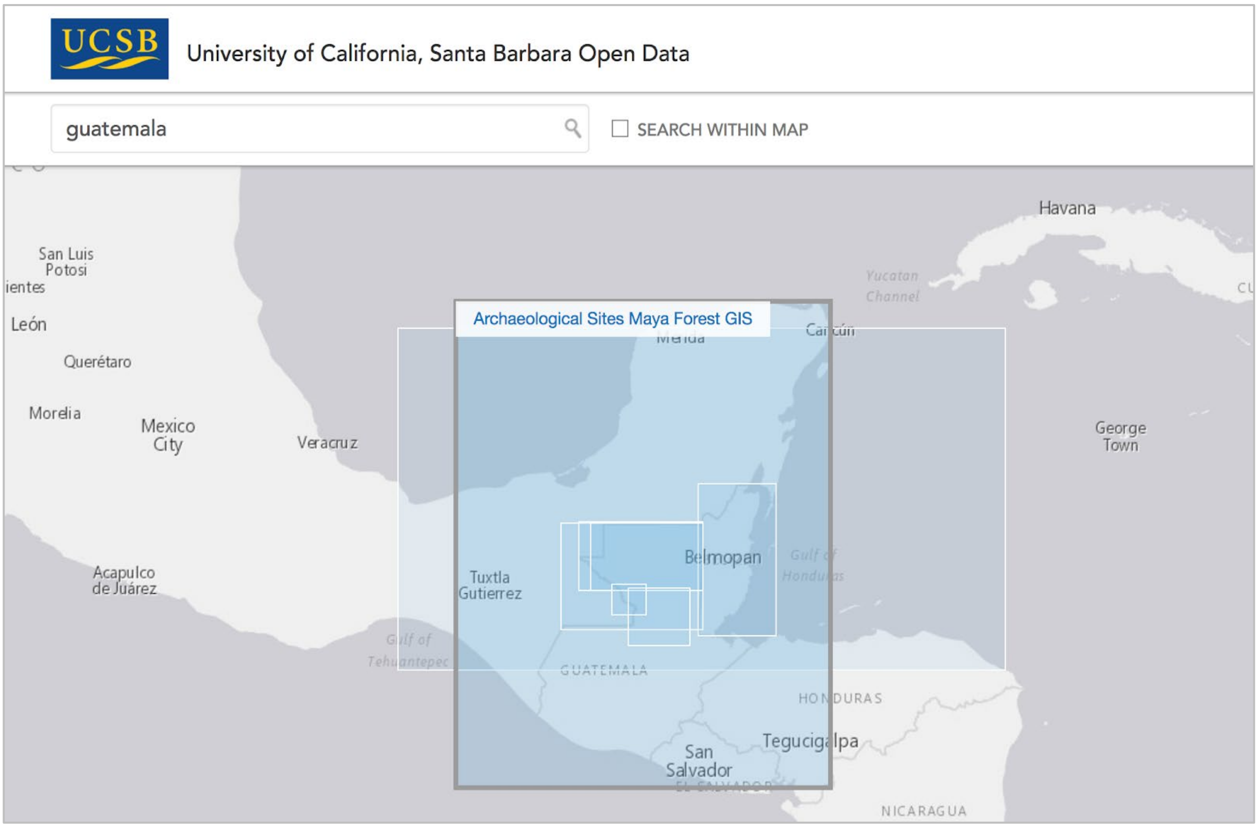


Figure 1. UCSB Open Data (via ArcGIS Online) offers users insights into the geographic distribution of research data.

Sharing and Discovering Research Spatially

To support spatial discovery, the UCSB Library and the Center for Spatial Studies have developed a protocol that allows researchers to provide key metadata elements to geographically reference their resources, thus making geographic location explicit (Lafia and Kuhn 2018). In this way, diverse resources hosted across various internal and external repositories can be made spatially discoverable. UCSB's open data site supports hosting for a wide range of data formats, including files like CSVs, and URL links to externally hosted content and nongeographic data, such as documents, images, and tables. Once described spatially, datasets referenced in research publications are indexed and made discoverable. Complementary work on a crosscutting base vocabulary describing the themes of data shared through ArcGIS Online also improves users' ability to discover data by using keyword-based search in spatial portals (Lafia et al. 2018).

Because all datasets contributed by researchers are supported by UCSB's open data site, they are also amenable to exploration and analysis in various web-based GIS. Access and contributions to the UCSB open data site are mediated by ArcGIS Online, which supports external and internal hosting. Users do not need to provide credentials (that is, to log in) to browse, download, or manipulate data from the site. To contribute, researchers follow a simple, extensible, and ultimately automatable workflow to describe and expose their research as data services. This approach also offers a more dynamic sharing of research products, allowing researchers to publish and maintain control of their original material through any means mandated by academic journals or grants while sharing their research with a much broader audience. It also reduces demand for libraries to provide data hosting through repositories. Data shared through UCSB's open data site increases the visibility of research by enabling geographic views and connecting research data to publications about them, allowing users to learn more about the research data regardless of where they are hosted.

Supporting Research Curation with Spatialization

Spatialization can take many forms in support of thematic integration (Bruggmann and Fabrikant 2016); thus, a self-organizing map and a network view of the same repository tell a different story about the thematic connections among research theses at UCSB. Expanding the notion of spatial discovery to such thematic spaces offers a spatial view and discoverability of research data that is nongeographic; coupling topic modeling with geographic views enables the spatial discovery and integration of research through interconnected geographic and topic spaces. The latest efforts to spatialize research data have resulted in a self-organizing map (fig. 2) and a network (fig. 3) derived from the text of thesis titles and abstracts has yielded interesting insights into patterns of related research themes (Lafia et al. 2019). The map is published as a web application through the UCSB open data site using ArcGIS Online, supporting thematic spatialization on a geospatial platform. The network is published using a reproducible script with parameters (number of edges, node size, etc.) that can be changed by the user.

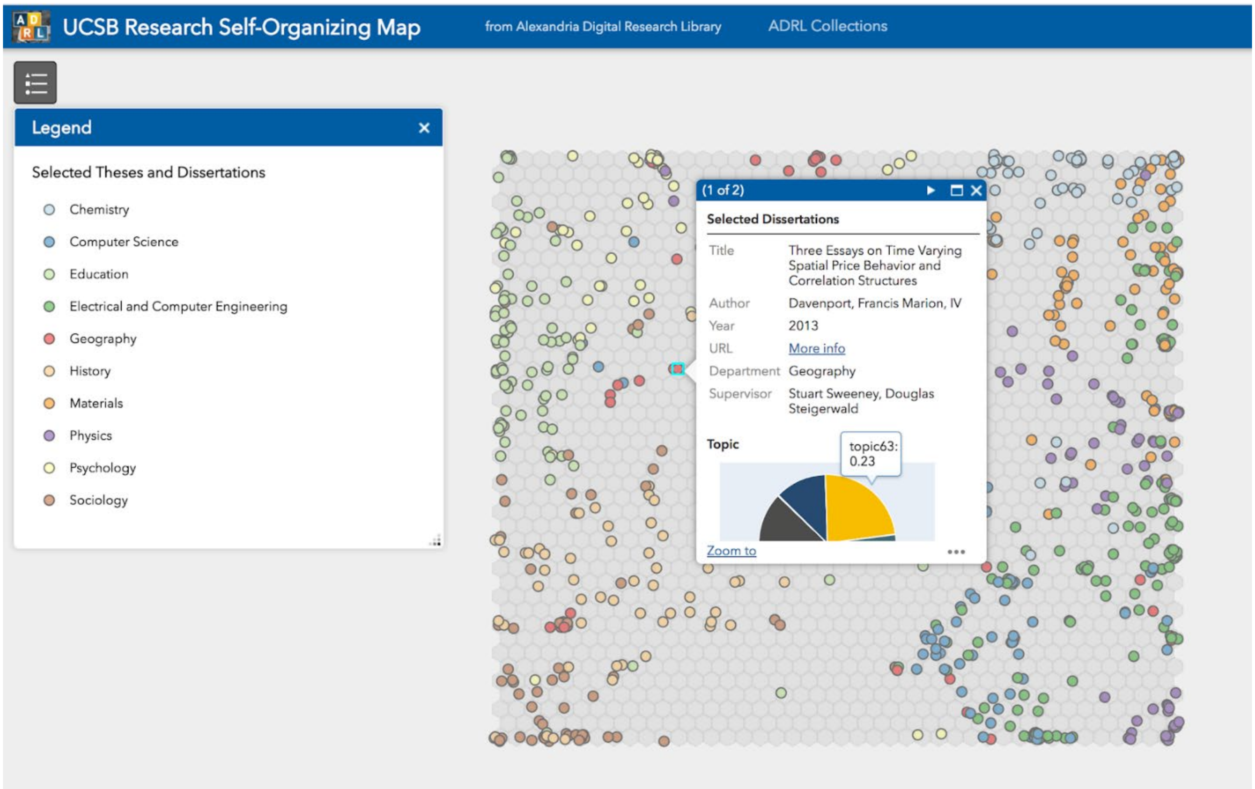


Figure 2. A self-organizing map places related research data (UCSB student theses) with related topics (shown as points on the map and color-coded by academic department) closer together.

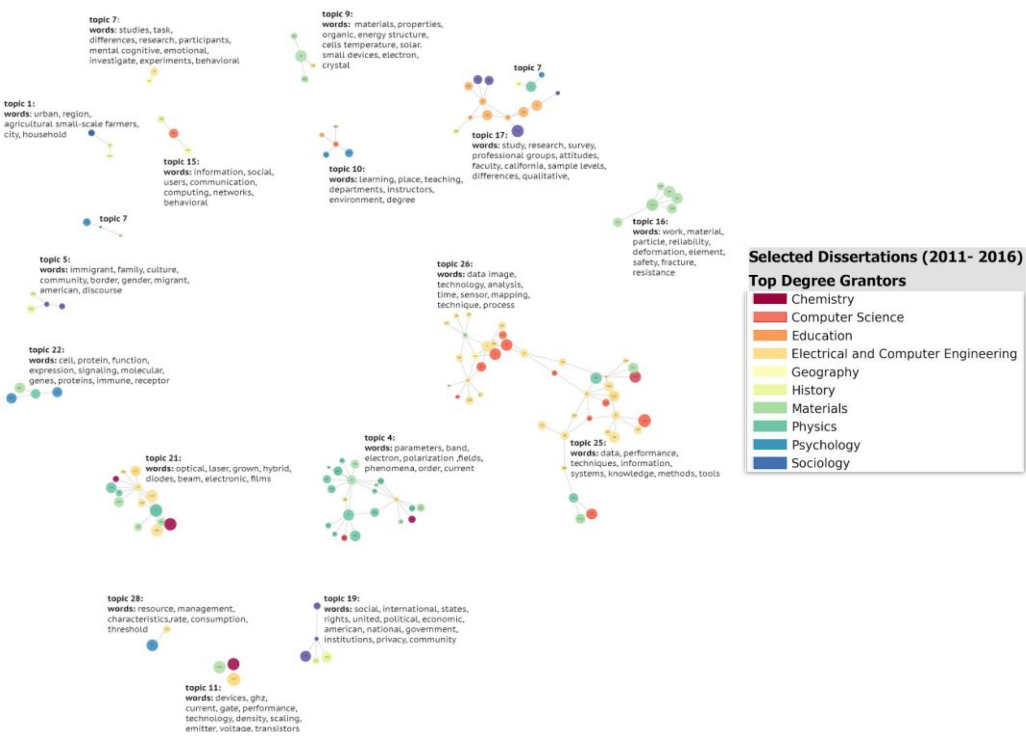


Figure 3. A network view links related research data (UCSB student theses shown as nodes) color-coded by academic department based on shared topics.

Future Work

The plans for spatial discovery at UCSB in the coming year include continued work on tools that link campus research data available through public research repositories. Consideration of temporal search (such as for data about historic periods) will incorporate the concept of events in search and discovery tools. Efforts to make these tools adaptive will also explore the benefits and challenges of using spatial quality concepts like granularity, accuracy, and provenance.

Conclusion

The work reported here has prioritized spatial perspectives at the university in a timely and concrete form. The UCSB Library's Interdisciplinary Research Collaboratory (see https://www.library.ucsb.edu/interdisciplinary-research-collaboratory) now supports researchers working to implement spatial analysis methods. Curation activities are also taking a spatial turn; the Alexandria Digital Research Library, which provides access to diverse research objects (such as publications, imagery, and audio recordings), anticipates enabling spatial search for these objects using GeoBlacklight (see https://geoblacklight.org/). The university is also supporting researchers with data curation, which has resulted in the adoption of a geospatially enabled DASH repository. As these developments align, they support the long-term goal of enabling spatial views and integration of university research and the serendipitous discovery of university research data across geographic regions and disciplines.

References

Bruggmann, André, and Sara I. Fabrikant. "How does GIScience support spatio-temporal information search in the humanities?" *Spatial Cognition & Computation* 16, no. 4 (2016): 255-271.

Lafia, Sara, Jon Jablonski, Werner Kuhn, Savannah Cooley, and F. Antonio Medrano. "Spatial discovery and the research library." *Transactions in GIS* 20, no. 3 (2016): 399-412.

Lafia, Sara, and Werner Kuhn. "Spatial Discovery of Linked Research Datasets and Documents at a Spatially Enabled Research Library." *Journal of Map & Geography Libraries* 14, no. 1 (2018): 21-39.

Lafia, Sara, Andrew Turner, and Werner Kuhn. "Improving Discovery of Open Civic Data." Paper presented at the 14th International Conference on Geographic Information Science (GIScience 2018). Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2018.

Lafia, Sara, Christina Last, and Werner Kuhn. Enabling the Discovery of Thematically Related Research Objects with Systematic Spatializations." In 10th International Conference on Spatial Information Theory (COSIT 2019). Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2019.

Mayernik, Matthew S., G. Sayeed Choudhury, Tim DiLauro, Elliot Metsger, Barbara Pralle, Mike Rippin, and Ruth Duerr. "The data conservancy instance: Infrastructure and organizational services for research data curation." *D-Lib Magazine* 18, no. 9/10 (2012).

Smith, Terence R., and James Frew. "Alexandria digital library." *Communications of the ACM* 38, no. 4 (1995): 61-62.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

Mapping User Sentiment in AR-Based Social Media

Chengbi Liu *, Sven Fuhrmann

Department of Geography and GeoInformation Science, George Mason University, Chengi Liu, cliu19@masonlive.gmu.edu,Sven Furhmann, sfuhrman@gmu.edu

* Corresponding author

Keywords: Augmented Reality, Location-Based Social Networks, Social Media, Online Social Networks, Kernel Density

Abstract

The prevalence of smartphones equipped with positioning modules enables users to utilize location-based social networks (LBSN) in various ways. LBSNs usually acquire spatial location information at the point of interest (POI) as text strings of addresses or a set of coordinates. However, except for what users explicitly share in their messages or postings, qualitative locality information and visual user sentiment are usually not captured and analyzed. An enhanced approach toward analyzing and mapping social media data is needed for augmented reality (AR)- and location-based social networks that automatically have implicit qualitative locality information and visual user sentiment included in the communication. This research uses WallaMe, an AR-integrated LBSN to assess these intangible properties. The methodology generates and assesses brightness and colorfulness indexes of users' backgrounds from images posted in WallaMe. Then, the approach compares the indexes with characteristics of the user-generated content (UGC), such as sentiment value and text length, to find any correlations. A kernel density analysis is implemented at various scales to identify spatial patterns of WallaMe posts. Significant, positive results have been found by applying this novel social media analysis approach. This research provides a new method for analyzing hyperlocal visual characteristics generated by AR-integrated LBSN, and a potential vehicle for connecting characteristics of the surrounding environment where social media posts are made with the UGC.

Introduction and Background

Online social networks (OSN) have grown from niche curiosities to a global phenomenon that is responsible for a significant fraction of overall Internet usage (Kumar, Novak, and Tomkins 2010, 337). People use OSNs for multiple purposes including expressing opinions, connecting with friends, sharing personal experiences, providing professional or educational assistance, marketing, or entertaining customers and clients. A vast amount of UGC is created and shared with various media, such as text, audio, photos, video, or 3D objects. Once publicly posted, this content becomes accessible for data analysis. OSNs have become an important source of valuable social media data for many domains in today's big data era (Ellison, Steinfield, and Lampe 2007, 1143; Mika 2007, 522; Palen 2008, 76).

Location-based social networks, a subcategory of OSNs, can be regarded as the convergence between location-based services (LBS) and OSNs (Fusco, Michael, Michael, and Abbas 2010, 230). Through smartphones equipped with positioning modules, LBSNs enable users to easily generate, view, and interact with spatial quantitative and qualitative information. All LBSN data is tightly coupled with location information acquired from multiple sources, including GPS sensors embedded in smartphones, place information expressed by users, posted messages or pictures, estimated distance to cell towers or Wi-Fi hot spots, etc. As a result, LBSNs provide an important basis to analyze human behavior in society and even predict spatiotemporal patterns of social events.

Traditionally, LBSNs acquire spatial location information at the points of interest as a string of addresses or a set of coordinates. Researchers can then associate such locations and UGC at the macro level to discover spatial user behavior patterns. However, the locality information at the micro level, such as the brightness and colorfulness of the surrounding environment or objects and events in the surrounding environment of the post, is usually not captured in traditional LBSNs and thus is missing a significant component in UGC analysis. For example, a Twitter user may post "Life is good!" while enjoying coffee in a café. There may be multiple reasons why the user posts such an expression: the peaceful background music, the cozy lighting, or the aroma and taste of the cup of coffee. These important qualitative elements of the surrounding environment are not captured by an address string or the name of the café. While many LBSNs support multimedia features such as images and video, they are not naturally associated with and integrated into the surrounding environment. This practice creates a situation that makes it difficult to extract locality information at a micro level and analyze its relationship to the UGC. However, the integration of AR into LBSNs might provide an approach toward such an analysis. This research outlines a methodology, based on AR-integrated LBSNs, to analyze the relationships between visual characteristics of hyperlocal information and characteristics of the UGC, primarily including text sentiment and text length.

AR overlays real-world views or scenes with virtual objects or information generated by computers that appear to visually coexist in the same space. Liu and Fuhrmann (2018, 780) outlined how AR-integrated LBSNs allow users to create, share, store, and modify AR content in an online community and highlighted the potential for online social networks. WallaMe is currently the most popular AR-LBSN platform worldwide (over 100,000 downloads on Google Play Store as of May 2019). WallaMe allows users to take a picture of the environment and overlay this picture with content (e.g., written notes, graffiti, drawings). WallaMe extracts the UGC, geotags it, and aligns the content with the original location and patterns of the background. Once processed, the AR representation of the UGC will be visible to other WallaMe users that are visiting the same location. Users can adjust privacy settings so that only selected users or groups have access to the posted content. WallaMe is a virtual doodle tool that merges real and AR experiences (fig. 1).

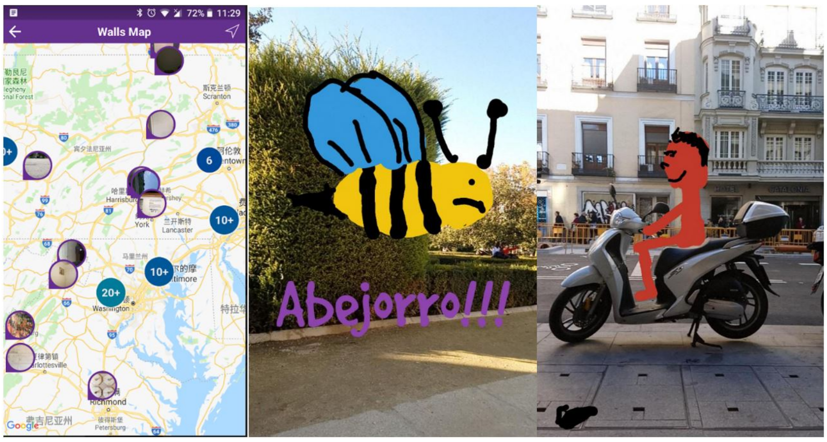


Figure 1. Screen captures of a map of WallaMe post locations along the US East Coast, and typical examples of WallaMe postings.

Methodology

The method extracts the hyperlocal information (the background pictures) generated in WallaMe, analyzes their visual characteristics (brightness and colorfulness), and compares the visual characteristics with UGC characteristics. The WallaMe dataset utilized for this study consisted of 46,591 unique AR records with spatiotemporal information, generated by 15,434 worldwide WallaMe users from April 2015 to October 2018. The data is publicly available through WallaMe's official website (http://walla.me). In the approach, the textual content generated by users is separated from the background image using Google's optical character recognition (OCR) tool. Five hundred records were randomly chosen and manually labeled to examine and calibrate the accuracy of the OCR tool. Afterward, Google's natural language API was used to analyze the sentiment of the extracted texts. Locality information was acquired via two measures computed by the RGB values of background images: brightness and colorfulness. Brightness represents the relative luminance of an image and was computed according to the standard sRGB color space (Anderson, Motta, Chandrasekar, and Stokes 1996, 242). Colorfulness is defined as the relative variety of colors in an image and was generated using an algorithm introduced by Hasler and Suesstrunk (2003, 92). This algorithm, based on their survey results, represents peoples' psychological perception of image colorfulness. Using brightness, colorfulness, and the total percentage of red, green, and blue background pixels as independent variables, the ordinary least squares (OLS) regression analysis was conducted between them and the UGC, including text sentiment and text length. Finally, a kernel density analysis was performed at different scales to examine if any spatial pattern in the dataset became visible.

Findings

Initial OLS results show that the visual characteristics of locality are not significantly correlated with user sentiment at the global level. However, as shown in table 1, text length is significantly correlated to the measure of brightness along with the percentage of green and blue pixels in the images (alpha=0.05). The results indicate that users are likely to post longer texts in environments that are brighter, have fewer green pixels, and contain more blue pixels.

As shown in figures 2 and 3, the kernel density function indicates spatial density distributions of the global and US-based WallaMe data. Orange pixels indicate count density, blue pixels indicate count density weighted by colorfulness, and red pixels indicate count density weighted by brightness.

Table 1. Correlation between Different Visual Characteristics and Text Length (OLS)

	Coefficients	Std. Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	0.207183	0.012075	17.15808	1.53E-65	0.183516	0.230851
Percentage of red pixels	0.00042	0.00023	1.825692	0.067911	-3.1E-05	0.000871
Percentage of green pixels	-0.0027	0.000401	-6.72201	1.84E-11	-0.00348	-0.00191
Percentage of blue pixels	0.002007	0.00026	7.719146	1.22E-14	0.001498	0.002517
Brightness	0.62448	0.09545	6.542446	6.19E-11	0.437389	0.81157
Colorfulness	0.000225	0.000153	1.471159	0.141263	-7.5E-05	0.000525

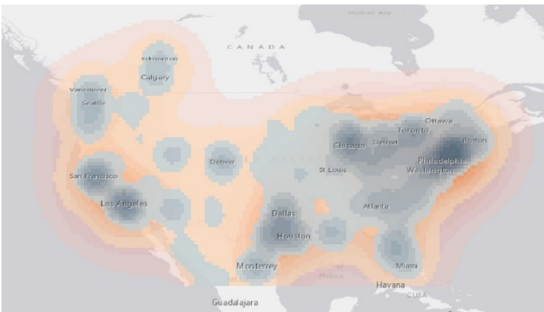


Figure 2. Density map of US-based WallaMe posts.

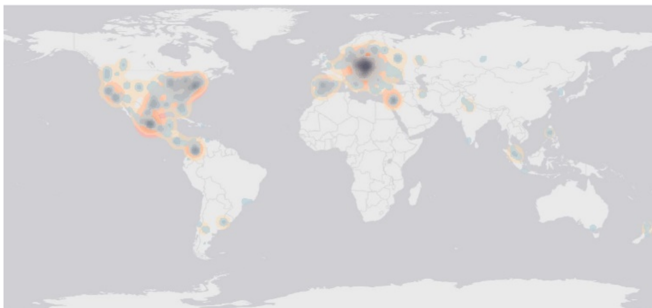


Figure 3. Density map of global WallaMe posts.

All density maps used a 9-class Jenks natural breaks classification method. It can be observed that, at both the global and the US level, the colorfulness-weighted distribution of WallaMe posts appears to be more fragmented than the mere occurrence of posts, whereas the brightness-weighted distribution appears to be smoother. This is likely due to the fact that there are more variations in image colors than in image brightness. In addition, the patterns shown on the map may suggest that people tend to post AR content in relatively colorful yet dark environments. As this research continues, these results will serve as the foundation to expand this nontextual social media content analysis approach.

Conclusion

This research provides a new approach toward analyzing hyperlocal visual characteristics generated by AR-integrated LBSNs and demonstrates a potential connection between visual characteristics of the surrounding environment and UGC. While text-based content analysis is currently mostly done for OSNs, the geographic information science (GIScience) field needs to develop new methods for analyzing visual media-based UGC. Additional advanced studies, based on the introduced methodology, will be done to discover other visual context and connections. While the results of this initial approach are mixed, we believe that AR-integrated LBSNs will become more prominently used by the public and communications industry over the next few years. Appropriate analysis methods, such as the one introduced here, will prepare and position the GIScience and cartography domains in the forefront of the scientific data analysis field.

References

Anderson, Matthew, Ricardo Motta, Srinivasan Chandrasekar, and Michael Stokes. 1996. "Proposal for a Standard Default Color Space for the Internet—sRGB." *Color and Imaging Conference* 1996, no. 1: 238–245. Society for Imaging Science and Technology.

Ellison, N. B., C. Steinfield, and C. Lampe. 2007. "The Benefits of Facebook 'Friends': Social Capital and College Students' Use of Online Social Network Sites." *Journal of Computer-Mediated Communication*, no. 12(4): 1143–1168.

Fusco, S. J., K. Michael, M. G. Michael, and R. Abbas. 2010. "Exploring the Social Implications of Location Based Social Networking: An Inquiry into the Perceived Positive and Negative Impacts of Using LBSN between Friends." *2010 Ninth International Conference on Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR)*: 230–237. IEEE.

Hasler, D., and S. E. Suesstrunk. 2003. "Measuring Colorfulness in Natural Images." *Human Vision and Electronic Imaging VIII,* no. 5007: 87–96. International Society for Optics and Photonics.

Kumar, R., J. Novak, and A. Tomkins. 2010. "Structure and Evolution of Online Social Networks." *Link Mining: Models, Algorithms, and Applications*: 337–357. Springer.

Liu, C., and S. Fuhrmann. 2018. "Enriching the GIScience Research Agenda: Fusing Augmented Reality and Location-based Social Networks." *Transactions in GIS*, no. 22(3): 775–788.

Mika, P. 2005. "Ontologies Are Us: A Unified Model of Social Networks and Semantics." *International Semantic Web Conference*: 522–536. Berlin, Heidelberg: Springer.

Palen, L. 2008. "Online Social Media in Crisis Events." *Educause Quarterly*, no. 31(3): 76–78.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

Hour of Cyberinfrastructure (Hour of CI)

Eric Shook [a, *], Forrest Bowlick [b], Karen Kemp [c], and Anand Padmanabhan [d]

[a] *Department of Geography, Environment, and Society, University of Minnesota, eshook@umn.edu*
[b] *Department of Geosciences, University of Massachusetts Amherst, fbowlick@umass.edu*
[c] *Spatial Sciences Institute, University of Southern California, kakemp@usc.edu*
[d] *Department of Geography and Geographic Information Science, University of Illinois at Urbana-Champaign, apadmana@illinois.edu*

* Corresponding author

Keywords: Spatial thinking, Geospatial data, Spatial modeling and analytics, Big data, Parallel computing

Introduction

Our world is filled with digital technologies, from satellites and sensors to smartphones and social media, that produce vast amounts of geospatial data. To make sense of these geospatial data and solve the world's problems, scholars and professionals in geographic information science (GIScience) combine geospatial technologies with computational technologies. There is an increasing need for GIScience to understand the entire spectrum of these cyber technologies from data production (e.g., satellites and sensors) to geospatial computing (e.g., supercomputers and cloud computing) to data delivery and visualization (e.g., web services). We define *cyber literacy for GIScience* to formalize this aspect of GIScience education.

Cyber Literacy for GIScience

Cyber literacy for GIScience is defined as the ability to understand and use established and emerging technologies to transform all forms and magnitudes of geospatial data into information for interdisciplinary problem solving (Shook et al. 2019). It is composed of eight core areas: cyber infrastructure, parallel computing, big data, computational thinking, interdisciplinary communication, spatial thinking, geospatial data, and spatial modeling and analytics. Acknowledging the diverse education needs of scientists and professionals, it is expected that individuals will have different levels of competencies across each of these eight core areas, but having a basic knowledge in each establishes them as being cyber literate. Attaining more advanced competency from intermediate to expert in a particular area requires more knowledge and skills.

By building the knowledge, skills, and practices of individuals operating in this GIScience space, those with spatial abilities can better take advantage of the affordances of cyber infrastructure, while those with computer science and programming abilities can better integrate and understand the nature of spatial data.

Hour of Cyberinfrastructure

Perhaps surprisingly, the first step toward cyber literacy is oftentimes a key challenge for many scientists and professionals. To address this challenge, we created the Hour of Cyberinfrastructure (Hour of CI) to serve as an entry point for each of the eight core areas. The Hour of CI is a National Science Foundation (NSF)-funded project that will create a foundation of learning materials aimed at cyber literacy (fig. 1). Its design is based on the model of the Hour of Code ("Hour of Code" n.d.), which offers one-hour tutorials to introduce computer science concepts. These have been accessed by hundreds of millions of K–12 students in over 180 countries. The Hour of CI project is developing 17 one-hour online, interactive lessons focused on the core cyber literacy for GIScience competencies. The target audience for these lessons is advanced undergraduate students, graduate students, and professionals in the social, environmental, and geospatial sciences. Our goal is to get Hour of CI lessons and instructional materials into classrooms across the nation to empower both next generation and current generation scientists and professionals to effectively use cyber infrastructure to solve spatial problems.

Figure 1. Hour of Cyberinfrastructure logo.

Hour of CI lessons are developed using Jupyter Notebook, which combines text, code, and visualizations in a single web-based document. Learners solve puzzles, interact with web elements, and write code in Jupyter Notebook. To provide computational resources, Hour of CI lessons are hosted on the GISandbox, which is a science gateway for GIScience research and education (Shook et al. 2018). GISandbox is hosted on the Extreme Science and Engineering Discovery Environment (XSEDE, Towns et al. 2016), which provides immediate and convenient access to advanced cyber infrastructure to apply students' new knowledge and skills. More about this project can be found at HourofCI.org.

Acknowledgments

We wish to thank Jennifer Moss for her valuable contribution in designing the Hour of CI logo. The material in this article is based on work supported by the National Science Foundation under grant number OAC-1829708. This work used the Extreme Science and Engineering Discovery Environment, which is supported by National Science Foundation grant number ACI-1548562. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

"Hour of Code." n.d. Accessed June 1, 2019. http://hourofcode.com.

Shook, Eric, Forrest J. Bowlick, Karen K. Kemp, Ola Ahlqvist, Patricia Carbajeles-Dale, David DiBiase, Eun-Kyeong Kim, Scott Lathrop, Britta Ricker, Patrick Rickles, Johnathan Rush, Jennifer N. Swift, and Shaowen Wang. 2019. "Cyber Literacy for GIScience: Toward Formalizing Geospatial Computing Education." *The Professional Geographer* 71, no. 2: 221–238.

Shook, Eric, Davide Del Vento, Andrea Zonca, and Jun Wang. 2018. "GISandbox: A Science Gateway for Geospatial Computing." In *Proceedings of the Practice and Experience on Advanced Research Computing*. PEARC'18: Practice and Experience in Advanced Research Computing, July 22–26, 2018, Pittsburgh PA. p. 44. New York, NY: ACM. DOI: 10.1145/3219104.3219150.

Towns, John, Timothy Cockerill, Maytal Dahan, Ian Foster, Kelly Gaither, Andrew Grimshaw, Victor Hazlewood, Scott Lathrop, Dave Lifka, Gregory D. Peterson, Ralph Roskies, J. Ray Scott, and Nancy Wilkins-Diehr. 2014. "XSEDE: Accelerating scientific discovery." *Computing in Science & Engineering* 16, no. 5: 62–74.

Semantically Supported Linked Data Mapping

Dalia E. Varanka

U.S. Geological Survey, dvaranka@usgs.gov

Keywords: Linked geospatial data maps, Geospatial semantics, Cartographic ontology

Abstract

Semantic technology based on the Resource Description Framework (RDF) modeling environment has introduced new data management capabilities that can lead to innovative cartographic techniques. This report describes research toward more semantically expressive linked geospatial data mapping, topics of research, and an avenue for further international collaboration.

Introduction

Four- and five-star linked open data (LOD) employs the World Wide Web Consortium (W3C) standard Resource Description Framework (RDF) to build semantic graph databases by interconnecting entity identifier name spaces and serializing the data as triples (Hyland et al. 2013). Data elements—each assigned a unique International Resource Identifier (IRI)—are linked together either by their shared base IRI, by a set of graph edges called triple properties, between the object nodes, by data dereferencing, or by another method.

The geospatial data community has enriched the initial LOD approach by creating controlled vocabularies for geographic coordinates (Brickley 2004), topological relations (Battle and Kolas 2012), and other space/time information (Koubarakis et al. 2018). Initial research on the geospatial linked data web focused on data models and data handling. Few cartographic visualizations and user interfaces have been developed despite the opportunity that the underlying technology offers for reconsidering widely used web mapping techniques. This paper summarizes initial developments and potential research for geospatial linked data mapping.

Techniques

Geospatial linked data mapping is often based on the direct transfer of geographic coordinates to web mapping resources in standard formats such as the Extensible Markup Language (XML)-based Keyhole Markup Language (KML) (Burggraf 2015). Data may have been preselected by specific attributes, but mapping is relatively static, though maps may include links to other related web pages as marginal information. Styling is separately processed from feature semantics, often based on an Open Geospatial Consortium, Inc. (OGC), standard (Müller 2006). This general mode of cartographic activity was productive for testing geospatial vocabulary and any unforeseen, syntactic errors and for correcting these semantics and pointing the way toward new data properties (Janowicz 2012).

A portrayal ontology for geospatial data compatible with many standard symbology graphic formats has been demonstrated (Fellah 2017). Results from Fellah's study advanced semantic mediation and services for linked geospatial data portrayal of "so called flat" data transference, but guidelines for many knowledge base functions beyond those of relational tables, such as entity classification (the recovery of missing entity properties) and link prediction (completion of missing data), remain untried. Cartographic ontologies for expert mapping systems (Smith 2010) and geovisualization systems using semantic technologies (Huang and Harrie 2019) capture cartographic knowledge and make it transferable when embedded in different contexts and applications. Visualization capabilities are included in such expert systems.

A signature characteristic of LOD, the browseable-graph approach that enables information search by clicking on the map feature, was recently demonstrated (Varanka and Usery 2018). A user can select properties associated with a feature by clicking the link in a pop-up window. The click triggers a new query to the database to retrieve literal strings or objects linked by their IRI as either sets or instances. The new selection is displayed in graphical form on the interface and is ready for clicking to continue the follow-your-nose search process that is often used in LOD but not yet in cartography (Mai et al. 2016). Since this data is not constrained to geometric layers or subsets of layer records, and because each feature has a complete geometry object independent of table records, features can be displayed on its own, as sets across thematic domains, or in other flexible ways. The objective of the study by Varanka and Usery (2018) was to demonstrate that geospatial data in the form of JSON-LD objects can combined with graphical elements so that the data can be used from the interface as map features. Because the data is the map, the interface is rooted in and requires the integration of a broader geospatial semantic system architecture.

Prospects

Cartographic visualization based on semantic technologies has potential for new capabilities because of graph-based data models. Although many cartographic principles and practices persist for LOD mapping, the technological differences of the databases and required middleware, such as reasoners, create potential for new methods of mapping. These technological differences include the following: the transference of semantic detail found in IRIs, the generalization and extraction of subgraphs, the integration of data from various sources, leveraging properties as semantic criteria for set-based object classes, and semantics of map symbol design. Potential solutions to these challenges will impact system architecture for geospatial linked data.

The flexibility of graphs, unconstrained by table model designs, works well to integrate a wide variety of data formats. Semantic standards and controlled vocabularies support data integration through the reuse of their terms, and custom vocabularies for niche, regional, or social semantics can be linked to them through Web Ontology Language logical properties (Hitzler et al. 2012). This approach helps overcome data silos and provides a range of semantic information for complex scenarios. The semantic specifications of different pieces of data can be visually evaluated without having lost detail.

However, to be fully matched or aligned, graph data requires logical consistency. Logic is the primary priority of semantic models, and its application to an existing database has resulted in the identification of inconsistencies that require resolution (fig. 1). Cartographic portrayal of different data provenances and semantics requires design approaches that include reasoning validation.

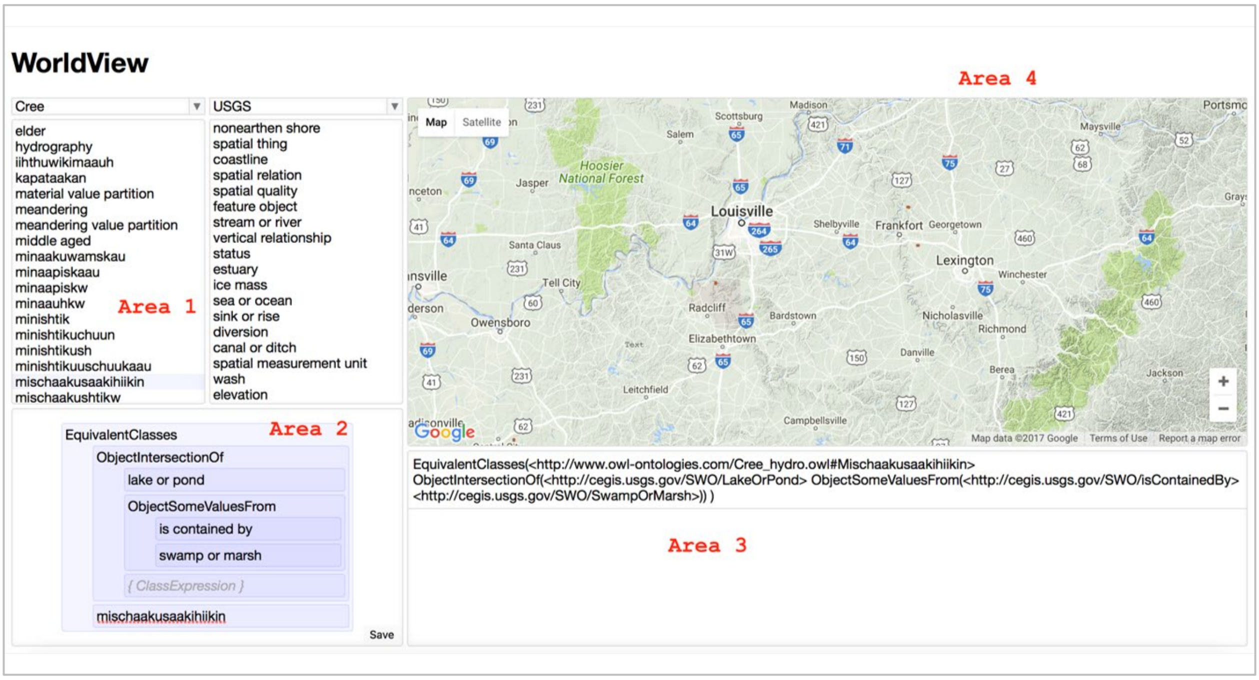


Figure 1. The WorldView map interface for aligning Cree and U.S. Geological Survey (USGS) hydrographic ontologies. Software designed by Cheatham (2018).

To date, linked geospatial data mainly uses point coordinates. One reason is that geometry coordinate strings serialized as Geography Markup Language (GML), Well-Known Text (WKT), or other formats, are challenging to store, access, and manipulate for spatial reasoning. One type of solution is to index Web Feature Services (WFS) through an RDF query interface (Zhao et al. 2017). Research on graph-based coordinate data storage (Regalia *et al*. 2017) and map projection transformation ontology (Usery 2019) is in progress.

Geometrical and topological spatial relations for coordinate data are well researched; a corpus of literature on space-time relation research also have been published. Patterns for the design of linked geospatial relations can support a broader range of geographic properties by employing formal logical properties instead of Euclidean geometry. Logical properties can model the semantics of place-based spatial relations. For example, the properties of a river gauge extend its coordinate point location in geographic information system (GIS) technology to map points in time and flow values. An ontological perspective on spatial relations can be modeled, and the logical nature of spatial properties supports spatial inference as well.

The wealth of information available from LOD graphs requires an automated logical query system as well. It is not known for certain how exploring and retrieving geographic information using an LOD map conforms with spatial cognition, uncertainty, and validation. For example, simplified or generalized multirelational data may serve users' needs as well as the full semantic specification. Further research on user-centered design in LOD interfaces would expand the technology to non-experts and to applications where speed or other qualities are a high priority.

Recommendations that address linked geospatial data have omitted discussions of rendering maps (van den Brink et al. 2018). Technical capabilities of how symbology graphic formats—such as scalable vector graphics (SVG)—can integrate with JavaScript Object Notation for Linked Data (JSON-LD) objects such as arrays is not widely understood, as rendering and data modeling have normally been accomplished in separate functions. To more closely align data and visualization, research is needed on how graphics and models can integrate.

Future Work

Innovative technologies offer data-handling opportunities that require reconsideration of current mapping techniques or the invention of new mapping practices. Cartographic research on graph-based geospatial data is gaining in scope. Initial proof-of-concept and validation applications both advance areas of LOD mapping and point to specific problems that are unresolved. The goals of LOD map visualization research are to better extract meaning from very large and other semantically obscure geospatial databases, quickly and easily evaluate multiple semantics for similar or related geographic entities from a diversity of mapping cultures, and clearly express published data to users.

The U.S. has proposed a new commission on geospatial semantics. The terms of reference for this commission are to disseminate information on the subject matter to International Cartographic Association (ICA) member nations through publications, joint meetings, seminars and websites, coordinate related activities around the world, and encourage and support user groups to participate in these activities. Formal semantics are not the only topic for the proposed commission; semantic study from within the scope of natural language, GIS, semiotics, and cultural and institutional aspects of semantics are also included.

References

Battle, R., and D. Kolas. 2012. "Enabling the Geospatial Semantic Web with Parliament and GeoSPARQL." *Semantic Web* 3, no. 4: 355–370.

Brickley, D. 2004. "W3C Semantic Web Interest Group." W3C. https://www.w3.org/2003/01/geo/.

Burggraf, D., ed. 2015. "OGC KML 2.3," OGC, accessed May 24, 2019. http://docs.opengeospatial.org/is/12-007r2/12-007r2.html.

Cheatham, M. 2018. "WorldView." GitHub. Last modified October 20, 2018. https://github.com/mcheatham/worldview.

Fellah, S., ed. 2017. "Testbed-12 Semantic Portrayal, Registry and Mediation Engineering Report." Open Geospatial Consortium. Last modified April 26, 2017. http://docs.opengeospatial.org/per/16-059.html.

Hitzler, P., M. Krötzsch, B. Parsia, P. F. Patel-Schneider, and S. Rudolph. 2012. "OWL 2 Web Ontology Language Primer (Second Edition)." W3C https://www.w3.org/TR/owl-primer/.

Huang, W., and L. Harrie. 2019. "Towards Knowledge-Based Geovisualization Using Semantic Web Technologies: A Knowledge Representation Approach Coupling Ontologies and Rules." *International Journal of Digital Earth*. doi: 10.1080/17538947.2019.1604835.

Hyland, B., G. Atemezing, M. Pendleton, and B. Srivastava. 2013. "Linked Data Glossary." W3C. http://www.w3.org/TR/ld-glossary/.

Janowicz, K. 2012." Place and Location on the Web of Linked Data," *STKO Lab* (blog), November 14, 2012, https://stko.geog.ucsb.edu/location_linked_data.

Koubarakis, M., K. Bereta, C. Nikolaou, and G. Stamoulis. 2018. "Linked Geospatial Data," in *Encyclopedia of Big Data Technologies*, edited by S. Sakr and A. Zomaya. Springer, Cham.

Mai, G., K. Janowicz, Y. Hu, and G. McKenzie. 2016. "A Linked Data Driven Visual Interface for the Multi-Perspective Exploration of Data across Repositories," in *Proceedings of the Fourth International Workshop on Visualization and Interaction for Ontologies and Linked Data*, edited by V. Ivanova, P. Lambrix, S. Lohmann, and C. Pesquita, vol. 2187, no. 93. Monterey, California: CEUR Workshop Proceedings, 2018. http://www.geog.ucsb.edu/~gengchen_mai/papers/2016-VOILA16_GeoLink.pdf.

Müller, M. 2006. "Symbology Encoding Implementation Specification." Open Geospatial Consortium, Inc. http://www.opengis.net/doc/IS/se/1.1.

Regalia, B., K. Janowicz, and G. McKenzie. 2017. "Revisiting the Representation of and Need for Raw Geometries on the Linked Data Web," in *Revisiting the Representation of and Need for Raw Geometries on the Linked Data Web*, vol. 2187, no. 93. Perth, Australia: LDOW '17. http://events.linkeddata.org/ldow2017/papers/LDOW_2017_paper_11.pdf.

Smith, R. A. 2010. "Designing a Cartographic Ontology for Use with Expert Systems." *Proceedings of a Special Joint Symposium of ISPRS Technical Commission IV & AutoCarto in Conjunction with ASPRS/CaGIS 2010 Fall Specialty Conference*, Orlando, Florida, November 15–19.

Usery, E. L. 2019. "Development of a Semantic Cartography Body of Knowledge." Presentation delivered at the 2nd US Semantic Technologies Symposium 2019, Durham, North Carolina.

Van den Brink, L., P. Barnaghi, J. Tandy, G. Atemezing, R. Atkinson, B. Cochrane, Y. Fathy, R. G. Castro, A. Haller, A. Harth, K. Janowicz, S. Kolozali, B. van Leeuwen, M. Lefrançois, J. Lieberman, A. Perego, D. Le Phuoc, B. Roberts, K. Taylor, and R. Troncy. 2018. "Best Practices for Publishing, Retrieving, and Using Spatial Data on the Web." *Semantic Web Journal*.

Varanka, D. E., and E. L. Usery. 2018. "The Map as Knowledge Base." *International Journal of Cartography* 4, no. 2: 201–223. doi: https://www.tandfonline.com/doi/full/10.1080/23729333.2017.1421004

Zhao, T., C. Zhang, and W. Li. 2017. "Adaptive and Optimized RDF Query Interface for Distributed WFS Data." *ISPRS International Journal of Geo-Information* 6, no. 4: 108.

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

A Framework for Analyzing and Visualizing Twitter Use Patterns during Natural Hazards

Lei Zou [a, *], Nina S. N. Lam [b], and Heng Cai [b]

[a] *Department of Geography, Texas A&M University, lzou@tamu.edu*
[b] *Department of Environmental Sciences, Louisiana State University, Nina Lam, nlam@lsu.edu, Heng Cai, hcai1@lsu.edu*

* Corresponding author

Keywords: Disaster resilience, Social media, Digital divide, Big data, Geovisualization

Abstract

Understanding how different communities prepare for, respond to, and recover from natural hazards is important for improving emergency management and disaster resilience. Twitter provides a form of location-based social media (LBSM) data. These data can be used in an innovative approach to observe human behavior during hazardous events and understand the effects of this behavior on disaster resilience. This paper describes a newly developed framework for visualizing and analyzing Twitter use patterns and its implications on disaster resilience. Through mapping disaster-related Twitter-reported activities by county during Hurricanes Sandy and Harvey using the methodology presented in the framework, we found significant geographical disparities of disaster-related Twitter use, and that counties with better socioeconomic conditions had greater use. These geographical disparities of Twitter use during disasters imply disproportionate access to hazard information and underlying socioeconomic conditions, which could influence the affected communities' resilience to the disasters.

Introduction

Human communities around the world are facing increasing threats from natural hazards due to global climate change and the impacts of human activities on the environment (Lam et al. 2016). The ability of a community to prepare for, respond to, recover from, and more successfully adapt to threats from natural hazards is defined as disaster resilience (Mihunov et al. 2018). When encountering natural hazards, communities with different threat levels, socioeconomic characteristics, and environmental conditions show diverse preparedness, response, and recovery behavior (Cai et al. 2016). However, data describing communities' behavior during natural hazards are difficult to acquire as data of this nature is not often found in traditional databases.

Twitter data are a form of LBSM data, which may be a promising data source for observing human reactions to disasters in near real time (Zou et al. 2018a & b). However, the process of analyzing and visualizing Twitter data is challenging. First, the amount of Twitter data is enormous, so storing and processing are subject to typical big data problems (Tsou 2015). Second, due to the amount of false and information on Twitter, robust algorithms to extract valuable and accurate information data are needed. Third, there is a lack of research on normalization methods to eliminate the biased user composition of Twitter data across space and time.

To address the above challenges, this article describes a Twitter data analysis and visualization framework, which has been applied to analyze the disaster-related Twitter usage during Hurricanes Sandy and Harvey (Zou et al. 2018a & b). This article reports the key findings, which shed light on the opportunities for using social media data in disaster research.

Twitter Data Analysis and Visualization Framework

Figure 1 shows the Twitter data analysis and visualization framework. The first step in using this framework involves data collection. Twitter data could be accessed from the application programming interfaces (APIs), services of commercial companies, web crawling, or free online library archives. Based on a set of customized keywords or regions, Twitter data that researchers are interested in can be extracted. The data collection is implemented in a Hadoop Distributed File System (HDFS) to process large amounts of data in parallel. All selected data are stored in a partitioned MongoDB database.

The second step is to determine the geographic location of each Twitter record. A geocoding module is implemented in the framework to estimate the location associated with each record through geotags and addresses in user profiles. Utilizing user addresses in their profiles for analysis has been challenging, as users may choose to input a very general address such as a state name or a city name instead of an accurate address, thus making a geographical analysis of Twitter use patterns unreliable. Therefore, a framework that allows the mapping and visualization of the locations of Twitter uses is critical in identifying where the problem is located so that adjustments to eliminate the biased user composition can be made.

The third step is content analysis, which investigates the semantics of collected texts, images, or videos. Methods such as natural language processing, machine learning and deep learning, and statistical analysis are embedded in this module (Chen et al. 2019). The geocoded and semantically parsed data are imported into the disaster-related Tweets (target data) or general Tweets (background data) databases for different research or application purposes.

The last step is geovisualization. The framework contains a list of Twitter indexes that are designed to provide a standardized means to analyze Twitter data across space, time, and events. These indexes include Ratio, Normalized Ratio (NRI), Sentiment, and Density. Each index represents an aspect of Twitter use. For example, the Ratio index is the number of target data values divided by the number of background data values, which reflects the general trend of public awareness about topics of interest while eliminating the bias of active Twitter users. Previous investigations have demonstrated the use of Ratio index in flood mapping (Li et al. 2018), damage estimation (Zou et al. 2018a), and citizen awareness assessment of climate change (Kirilenko and Stepchenkova 2014). All developed indexes could be computed using different spatial (e.g., national, county, or ZIP code levels) and temporal (e.g., weekly, daily, and monthly) scales.

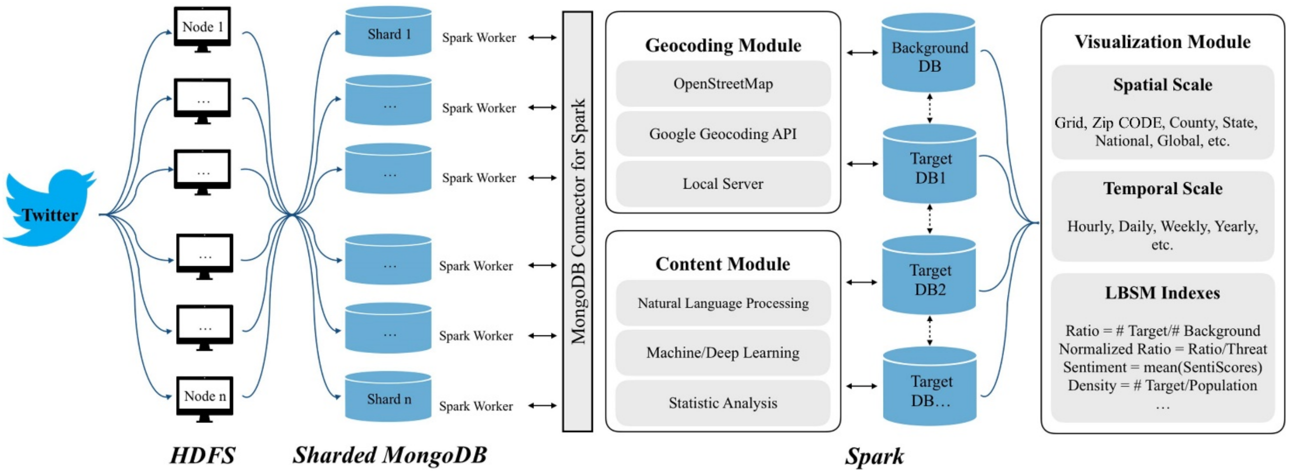


Figure 1. The Twitter data analysis and visualization framework (modified from Zou et al. 2018b).

Geographic and Social Disparities of Disaster-Related Twitter Use

Figure 2 shows two maps of county-level ratio indexes that were created in our previous study (Zou et al. 2018a & b). The map on the left relates to data about Hurricane Sandy, and the map on the right relates to Hurricane Harvey. These results demonstrate that the Ratio index can be used to compare Twitter use across space and time.

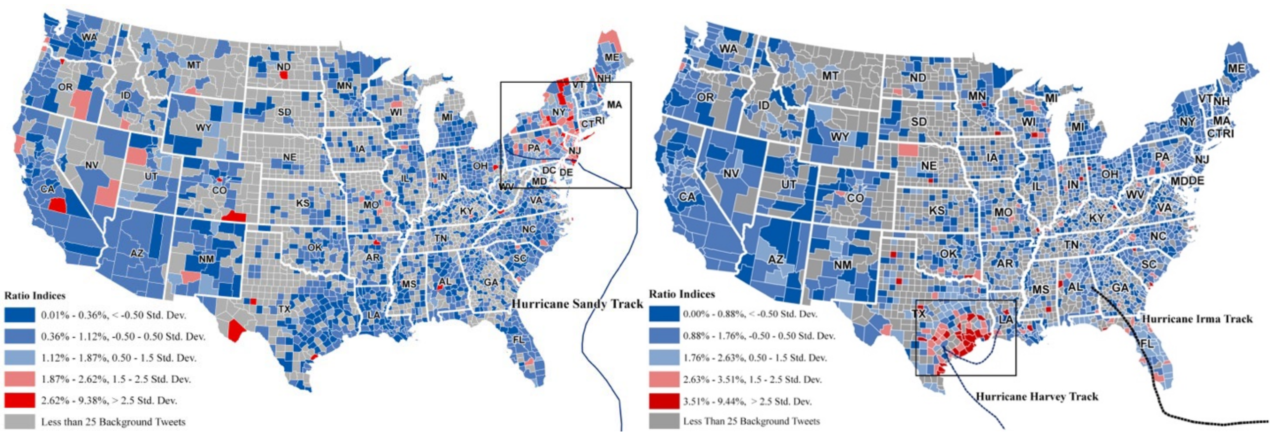


Figure 2. County-level ratio indexes during Hurricanes Sandy 2012 (left) and Harvey 2017 (right).

Ratio indexes could be further tabulated into the preparedness, response, and recovery phases of emergency management in the affected regions. Also, statistical analysis in our previous studies verified that counties that experienced higher threat levels from hurricanes had higher Ratio index values, especially in the preparedness phase. When adding socioeconomic data by county to the analysis, we found that counties with better socioeconomic conditions had higher Ratio index values than those with poorer socioeconomic conditions, and this relationship was most significant in the response phase. Communities that suffered more damage usually sustained a longer and more intensive disaster-related discussion in the recovery phase, indicating the potential of using Twitter data for rapid damage estimation. These results suggest that more resilient communities are more aware of using Twitter to respond to the hazard event, implying that people in these communities are more likely to be using Twitter to access hazard information, request rescue assistance, or report damages. Thus, these areas are likely to recover more quickly from the hazardous event (Zou et al. 2018a & b).

Conclusion

This article describes a relatively new framework designed to analyze and visualize Twitter use during hazard events. In the framework, big, noisy, and biased Twitter data are converted into standardized indexes that can be tabulated at multiple spatial-temporal scales. Through visualizing and analyzing the Ratio indexes and related socioeconomic data during Hurricanes Sandy and Harvey, we found that communities with better socioeconomic conditions are more likely to Tweet during the hazard events, implying that they are more aware of the event and more likely to access hazard information and recover quickly from the event.

A framework promoting standardized indexes like the Ratio index has many advantages. First, the framework could be applied to Twitter data on a variety of topics. Future comparative studies could provide new perspectives on how Twitter users react to different topics. Second, the framework makes it possible to observe human behavior throughout the cycle of emergency management. The knowledge gained from these observations could be used to investigate the digital divide and better understand how to mitigate it. Third, the framework could be applied to visualize a number of location-based problems, such as finding locations of disaster victims requesting rescue assistance using social media platforms. Such a visualization could guide first responders and volunteers to quickly identify people in need of help during emergencies.

Funding

This research is funded by two research grants from the US National Science Foundation (NSF): one under the Social, Behavioral and Economic Sciences (SBE) Office of Multidisciplinary Activities (SMA) organization in Interdisciplinary Behavioral and Social Science Research (IBSS) Program (Award No. 1620451) and the other under the NSF Social and Economic Sciences (SES) Division Hurricane Harvey 2017 Program (Award No. 1762600). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agencies.

References

Cai, Heng, Nina S.N. Lam, Lei Zou, Yi Qiang, and Kenan Li. 2016. "Assessing Community Resilience to Coastal Hazards in the Lower Mississippi River Basin." *Water*, 8:2, 46. https://doi.org/10.3390/w8020046.

Chen, Xingyu, Lei Zou, and Bo Zhao. 2019. "Detecting Climate Change Deniers on Twitter Using a Deep Neural Network." *Proceedings of the 2019 11th International Conference on Machine Learning and Computing*, 204–210. ICMLC '19. New York, NY, USA: ACM. https://doi.org/10.1145/3318299.3318382.

Kirilenko, Andrei P. and Svetlana O. Stepchenkova. 2014. "Public Microblogging on Climate Change: One Year of Twitter Worldwide." *Global Environmental Change*, 26 (May 2014): 171–82. https://doi.org/10.1016/j.gloenvcha.2014.02.008.

Li, Zhenlong, Cuizhen Wang, Christopher T. Emrich, and Diansheng Guo. 2018. "A Novel Approach to Leveraging Social Media for Rapid Flood Mapping: A Case Study of the 2015 South Carolina Floods." *Cartography and Geographic Information Science*, 45:2, 97–110. https://doi.org/10.1080/15230406.2016.1271356.

Mihunov, Volodymyr V., Nina S. N. Lam, Lei Zou, Robert V. Rohli, Nazla Bushra, Margaret A. Reams, and Jennifer E. Argote. 2018. "Community Resilience to Drought Hazard in the South-Central United States." *Annals of the American Association of Geographers*, 108:3, 739–55. https://doi.org/10.1080/24694452.2017.1372177.

Lam, Nina S. N., Margaret Reams, Kenan Li, Chi Li, and Lillian P. Mata. 2016. "Measuring Community Resilience to Coastal Hazards along the Northern Gulf of Mexico." *Natural Hazards Review*, 17:1, 04015013. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000193.

Tsou, Ming-Hsiang. 2015. "Research Challenges and Opportunities in Mapping Social Media and Big Data." *Cartography and Geographic Information Science*, 42:sup1, 70–74. https://doi.org/10.1080/15230406.2015.1059251.

Zou, Lei, Nina S. N. Lam, Heng Cai, and Yi Qiang. 2018a. "Mining Twitter Data for Improved Understanding of Disaster Resilience." *Annals of the American Association of Geographers*, 108:5, 1422–41. https://doi.org/10.1080/24694452.2017.1421897.

Zou, Lei, Nina S. N. Lam, Shayan Shams, Heng Cai, Michelle A. Meyer, Seungwon Yang, Kisung Lee, Seung-Jong Park, and Margaret A. Reams. 2018b. "Social and Geographical Disparities in Twitter Use during Hurricane Harvey." *International Journal of Digital Earth*, 0:0, 1–19. https://doi.org/10.1080/17538947.2018.1545878

International Cartographic Association
Association Cartographique Internationale

Cartography and Geographic Information Society

Geovisual Analytics and Interactive Machine Learning for Situational Awareness

Morteza Karimzadeh [a, *], Luke S. Snyder [b], David S. Ebert [b]

[a] *Department of Geography, University of Colorado Boulder (formerly at Purdue University), karimzadeh@colorado.edu*
[b] *School of Electrical and Computer Engineering, Purdue University, snyde238@purdue.edu, ebertd@purdue.edu*

* Corresponding author

Keywords: Human in the loop, Machine learning, Visual analytics, Geovisualization, Social media

Abstract

The first responder community has traditionally relied on calls from the public, officially provided geographic information, and maps for coordinating actions on the ground. The ubiquity of social media platforms created an opportunity for near real-time sensing of a situation (e.g., an unfolding weather event or crisis) through volunteered geographic information. In this article, we provide an overview of the design process and features of Social Media Analytics Reporting Toolkit (SMART), a visual analytics platform developed at Purdue University for providing first responders with real-time situational awareness. We attribute its successful adoption by many first responders to its user-centered design, interactive (geo)visualizations, and interactive machine learning, thus giving users control over analysis.

Introduction

Social media has created an opportunity for researchers and practitioners to harvest volunteered geographic information for various purposes, including sentiment analysis, mobility and movement studies, polling, and market analysis. The real-time nature of social media makes it an excellent source for situational awareness and crisis management. For instance, several emergency operation centers' staff members have told us that they receive useful information about a situation on the ground at least 10–15 minutes prior to receiving phone calls from the public. However, the data obtained through social media is big, with relevant information overwhelmed by noise. It is crucial to harness and summarize the sea of data according to first responders' needs, which may vary depending on the situation.

Social Media Analytics and Reporting Toolkit

Social Media Analytics Reporting Toolkit (SMART) is an interactive, web-based visual analytics system targeted for first responders who may not have computational expertise (Zhang et al. 2017; 2014; Snyder, Lin, et al. 2019). It leverages many integrated algorithms and technologies for scalable, real-time, and interactive social media (currently, only public Tweets) analysis and visualization. SMART allows users to filter Tweets based on their topic through the inclusion and exclusion of keywords. Further, it provides interactive, human-in-the-loop machine learning of relevant posts to each analytical scenario. After Tweets are filtered, users can use multiple interactive visualizations to view topics aggregated in time (e.g., the ThemeRiver visualization [Havre et al. 2002]), over space (e.g., spatial topic modeling, spatial content lenses, and spatial topic lenses), by topics (e.g., word clouds and topic modeling), or by combinations of these dimensions. These different visualizations are linked, allowing users to further inspect and drill down to certain topics, spatial extents, or time periods at multiple scales of aggregation. SMART combines advanced statistical modeling, text analytics, machine learning, and novel anomaly detection techniques augmented by human expertise so that users can identify trending and abnormal topics on social media. Figure 1 provides an overview of SMART's user interface.

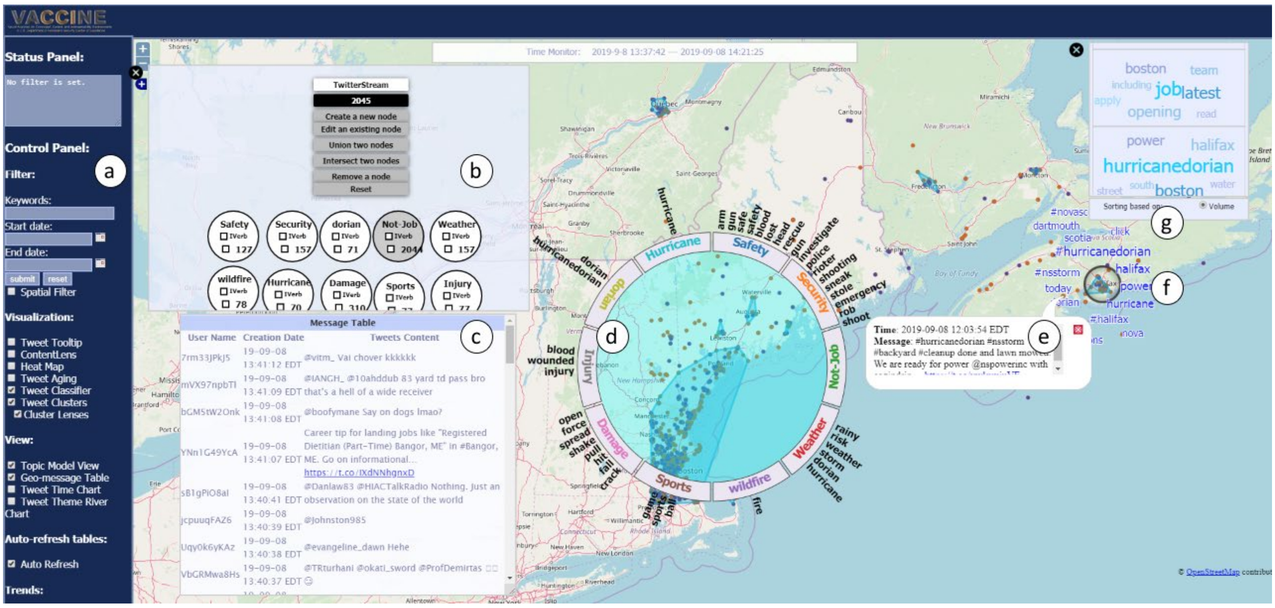


Figure 1. SMART's web interface and interactive visualizations. The control panel (a) allows users to activate different components. The Tweet classifier (b) allows users to construct semantic keyword filters to identify relevant information. The geomessage table (c) lists Tweets for direct content analysis. The (d) cluster lens provides a radial layout of keywords derived from each Tweet classifier and used within a spatial region. The Tweet tool tip (e) allows users to directly view a Tweet's content from the map. The content lens (f) uses topic modeling to highlight the most frequently used words within an area. The word cloud view (g) uses topic modeling to extract trending topics and associated keywords.

Giving users maximum control of system content, behavior, and visualization has been central to SMART's success. We fulfilled this vision through customizable topical filters, interactive maps and visualizations, and interactive machine learning with minimal user feedback. Even though keyword filtering provides basic functionality for users to narrow the stream of social media posts down to the topics that they are interested in, the amount of noise and irrelevant information may still be overwhelming. Furthermore, user intentions and situational requirements vary from one event to another. For instance, a particular topic such as traffic may be of interest during an event such as a wildfire adjacent to highway networks but not during a wildfire that occurs in the wilderness. Therefore, SMART provides interactive learning functionality (based on a shallow neural network) in which users can mark posts as being relevant or not relevant. According to our evaluations, the system learns from the user quickly, with more than ~50 percent accuracy after 50 labels have been provided by the user, and reaching accuracies up to ~80 percent in identifying relevant posts after ~200 labels have been provided by the user (Snyder, Lin, et al. 2019). However, combined with interactive sorting and zooming, even fewer clicks by the user sufficiently tailors the system and the visualized content to user analytical needs. Figure 2 shows the results of interacting with the system after only 20 clicks by the user to train the integrated neural network model and sorting the Tweets based on relevance to the topic—in this case, "weather"—chosen by a user. This functionality enables first responders to quickly identify relevant information from social media that also includes large amounts of noisy and irrelevant data.

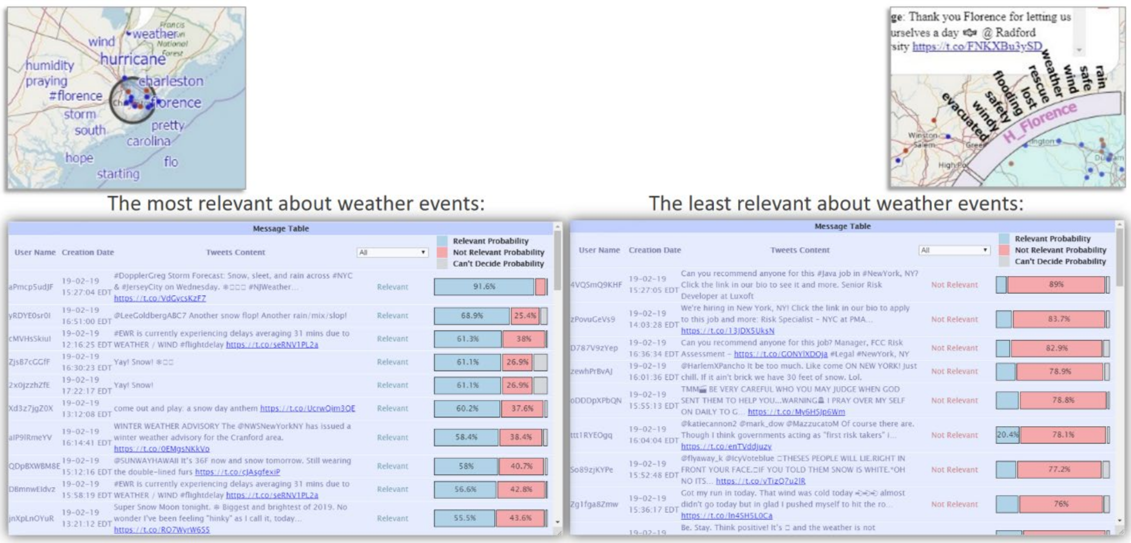


Figure 2. Interactive machine learning for classifying social media posts as relevant/irrelevant to a weather event. By training a classifier, the analyst can see relevant Tweets on interactive maps. The table on the left shows the Tweets sorted by descending relevance to the topic of weather, and the table on the right shows Tweets sorted by ascending relevance. These are achieved after only 20 user clicks, which is a significant improvement over mere keyword-based filtering.

User-Centered Design and the Consequent Adoption of SMART

SMART was developed at Purdue University with the goal of supporting shared situational awareness so that decision-makers at every level have access to the same crowdsourced information from public data feeds. Central to SMART's design and development have been the continuous stakeholder engagement, requirement analysis, demos, interviews, feedback sessions, agile development, and refinements (Snyder, Karimzadeh, et al. 2019). Through the adoption, modification, improvement, and extension of state-of-the-art approaches (Havre et al. 2002, Karimzadeh et al. 2019, Bosch et al. 2011, Thom et al. 2012), SMART's development has primarily been focused on meeting the user requirements rather than exploring academic curiosity. However, the real-world use of SMART has enabled significant research accomplishments at the forefront of computer science and (geographic) information science, reported in various conference and journal articles (Chae et al. 2014; Zhang et al. 2017; Snyder, Lin, et al. 2019; Snyder, Karimzadeh, et al. 2019).

SMART has been successfully used in many events since its first utilization at the Boy Scouts of America's 2013 National Scout Jamboree. Local emergency response departments, campus police departments, nongovernmental organizations, and the US Coast Guard (USCG) have used SMART extensively since then, with ~20 organizations actively using it for special events (e.g., festivals) or natural events (e.g., hurricanes, floods). For instance, during the 2017 hurricane season, the USCG used SMART to find people in distress and to target search and rescue efforts. SMART was also used for the 2016 Republican National Convention in Cleveland, Ohio; for the 2017 Presidential Inauguration; for the 2018 and 2019 State of the Union Addresses in Washington, DC; by state-level officials for the Thunder Over Louisville event; and for the Cincinnati Riverfest and several state fairs. In each case, Purdue University researchers trained the prospective end users in a one-hour webinar; sought feedback after use; and made necessary modifications to the system, which have now occurred over the course of several years.

Purdue University has licensed SMART to a startup company—supported by Purdue Foundry—for commercialization. This company will continue to support the existing end-user groups and enhance the scalability and usability of SMART for more users in the future.

Conclusion and Future Directions

Social media has proved useful in facilitating situational awareness, provided that computational methods and human expertise are combined in efficient ways. We achieved this through iterative, user-centered design with constant stakeholder engagement. Central to our approach was the full utilization of previous research while keeping users and interactivity in mind. We designed (or adopted), optimized, and evaluated our computational methods in interactive settings to ensure full user control over the system and its content. Users train the integrated machine learning models based on their needs; therein lies one of the primary reasons for SMART's successful adoption.

Moving forward, research and development should focus on both the technical and ethical aspects of privacy and geolocation to sustain situational awareness for social good while preventing adverse use or breaking society's trust. Many users are hesitant to share their geolocation directly but still provide approximate geolocation in their profiles, providing an opportunity for situational awareness with reduced chances of unwittingly flouting user privacy.

Acknowledgement

This material is based upon work funded by the US Department of Homeland Security (DHS) under DHS Award No. 2009-ST-061-CI0003, DHS Cooperative Agreement No. 2014-ST-061-ML0001, and DHS Science and Technology Directorate Award No. 70RSAT18CB0000004.

References

Bosch, H., D. Thom, M. Wörner, S. Koch, E. Püttmann, D. Jäckle, and T. Ertl. 2011. "ScatterBlogs: Geo-Spatial Document Analysis." In *2011 IEEE Conference on Visual Analytics Science and Technology* (*VAST*), 309–10. https://doi.org/10.1109/VAST.2011.6102488.

Chae, Junghoon, Dennis Thom, Yun Jang, SungYe Kim, Thomas Ertl, and David S. Ebert. 2014. "Public Behavior Response Analysis in Disaster Events Utilizing Visual Analytics of Microblog Data." *Computers & Graphics* 38(0):51–60. https://doi.org/http://dx.doi.org/10.1016/j.cag.2013.10.008.

Havre, Susan, Elizabeth Hetzler, Paul Whitney, and Lucy Nowell. 2002. "ThemeRiver: Visualizing Thematic Changes in Large Document Collections." *IEEE Transactions on Visualization and Computer Graphics* 8(1): 9–20.

Karimzadeh, Morteza, Scott Pezanowski, Jan Oliver Wallgrün, Alan M. MacEachren, and Jan Oliver Wallgrün. 2019. "GeoTxt: A Scalable Geoparsing System for Unstructured Text Geolocation." *Transactions in GIS* 23(1): 118–36. https://doi.org/10.1111/tgis.12510.

Snyder, L. S., M. Karimzadeh, C. Stober, and D. S. Ebert. 2019. "Situational Awareness Enhanced through Social Media Analytics: A Survey of First Responders." In *IEEE International Symposium on Technologies for Homeland Security*. Woburn, MA.

Snyder, L. S., Y. Lin, M. Karimzadeh, D. Goldwasser, and D. S. Ebert. 2019. "Interactive Learning for Identifying Relevant Tweets to Support Real-Time Situational Awareness." *IEEE Transactions on Visualization and Computer Graphics* 1. https://doi.org/10.1109/TVCG.2019.2934614.

Thom, D., H. Bosch, S. Koch, M. Wörner, and T. Ertl. 2012. "Spatiotemporal Anomaly Detection through Visual Analysis of Geolocated Twitter Messages." In *2012 IEEE Pacific Visualization Symposium* (*PacificVis*), 41–48. https://doi.org/10.1109/PacificVis.2012.6183572.

Zhang, Jiawei, S. Afzal, D. Breunig, J. Xia, J. Zhao, I. Sheeley, J. Christopher, et al. 2014. "Real-Time Identification and Monitoring of Abnormal Events Based on Microblog and Emergency Call Data Using SMART." In *2014 IEEE Conference on Visual Analytics Science and Technology (VAST)*, 393–94. https://doi.org/10.1109/VAST.2014.7042582.

Zhang, Jiawei, Junghoon Chae, Chittayong Surakitbanharn, and David S. Ebert. 2017. "SMART: Social Media Analytics and Reporting Toolkit." In *The IEEE Workshop on Visualization in Practice*, 1–5.