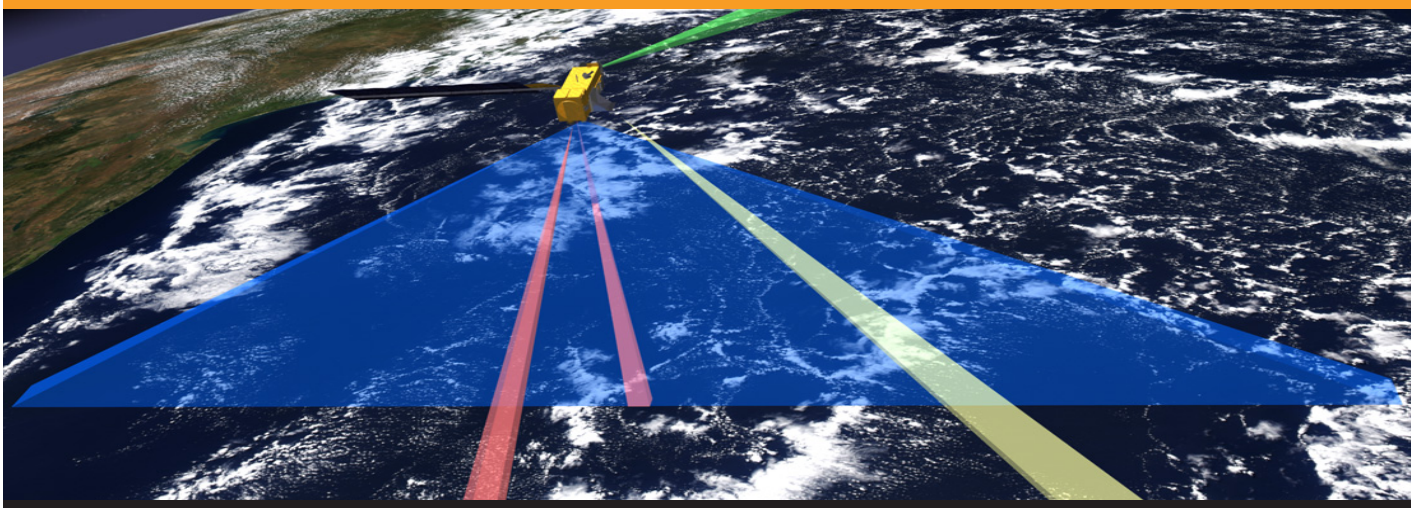
PE&RS

June 2022 Volume 88, Number 6

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING The official journal for imaging and geospatial information science and technology

The 4th Edition of the *Manual of Remote Sensing!*

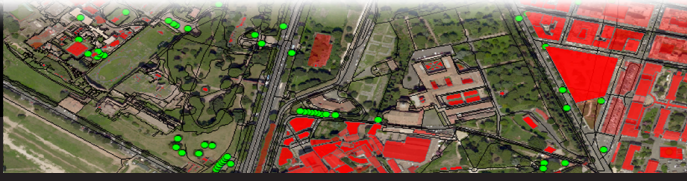


MANUAL OF REMOTE SENSING

Fourth Edition

The *Manual of Remote Sensing, 4th Ed.* (MRS-4) is an "enhanced" electronic publication available online from ASPRS. This edition expands its scope from previous editions, focusing on new and updated material since the turn of the 21st Century. Stanley Morain (Editor-in-Chief), and co-editors Michael Renslow and Amelia Budge have compiled material provided by numerous contributors who are experts in various aspects of remote sensing technologies, data preservation practices, data access mechanisms, data processing and modeling techniques, societal benefits, and legal aspects such as space policies and space law. These topics are organized into nine chapters. MRS4 is unique from previous editions in that it is a "living" document that can be updated easily in years to come as new technologies and practices evolve. It also is designed to include animated illustrations and videos to further enhance the reader's experience.

MRS-4 is available to ASPRS Members as a member benefit or can be purchased by non-members. To access MRS-4, visit https://my.asprs.org/mrs4.



edited by: Stanley A. Morain,
Michael S. Renslow and Amelia M. Budge

To have your press release published in *PE&RS*, contact Rae Kelley, rkelley@asprs.org.

INDUSTRYNEWS

ANNOUNCEMENTS

URISA's Vanguard Cabinet is proud to host the sixth annual Digital Competition to promote the GIS profession and the attendance of students and young and emerging professionals at GIS-Pro 2022 in Boise, ID (October 2-6, 2022). The competition will be held virtually this summer, and the participants selected to present will receive a complimentary one-year URISA membership. The top three presenters will also be awarded a complimentary GIS-Pro 2022 registration and the opportunity to present their work during the conference.

This competition is an opportunity for students and YPs to showcase a project of their choice, ideally one that utilizes web and mobile platforms such as ArcGIS Online, Tableau, Mapbox, or Power BI. Projects should showcase the visualization functions of these platforms while also demonstrating knowledge and proficiency in spatial analytics, cartographic design, and/or geospatial techniques.

To enter the competition, participants should submit a link to their virtual project and include a 150 to 300-word project abstract detailing the project design, analysis, and implementation. Selected entries will deliver a 3-5 minute ignite-style live presentation via Zoom on their project's use of an online visualization platform, geospatial technology, and spatial thinking. The presentations will be judged by a panel of URISA leaders, and based on the judges' assessments, three presenters will be selected to present their work at GIS-Pro 2022. (The top three presenters will be awarded a full GIS-Pro 2022 registration, $500 travel stipend, and the opportunity to present their work live at GIS-Pro 2022 in Boise.)

Abstracts are due on or before June 10. For more information, visit www.urisa.org/gispro-studentsyps.

Nearmap's high-resolution aerial imagery of major urban areas in the United States, Canada, Australia, and New Zealand will soon be available through UP42. The initial offering will include the Nearmap vertical imagery, which is updated multiple times each year at 5.5- to 7.5-cm (2.2" to 3") spatial resolution for more over 1740 urban areas in the US and over 100 in Australia.

With global headquarters in Sydney, Australia, vertical imagery from Nearmap provides an orthogonal imagery base layer that offers consistent clarity, precision, and spatial detail for cities and their surrounding areas. In the United States alone, coverage includes more than 80% of its population with 308,000 unique square miles – including some of the most rapidly growing municipalities – surveyed each year.

The Nearmap Vertical imagery archive dates from 2011 in Australia and New Zealand, and 2014 in the US – with an annual refresh schedule of 3X to 6X per year. New imagery is orthorectified, georeferenced, and uploaded to the cloud for purchase within days of collection.

"Our partnership with Nearmap delivers value to UP42 customers by providing direct access to high-precision urban imagery of remarkable quality and detail," said UP42 CEO Sean Wiid. "The extensive Nearmap archive and refresh rate combined with other geospatial data sets on the UP42 platform enable highly detailed monitoring applications related to asset management in the utility, construction, and local government sectors."

UP42 is lowering the barrier to entry for customers to extract unique geographic insights and create scalable geospatial solutions. To this end, customers can integrate the Nearmap Vertical imagery with other data sets available from UP42. The marketplace currently contains over 160 products from more than 50 of the world's leading geospatial organizations.

"We are pleased to deliver our current, clear and consistent high-resolution imagery to UP42 customers," said Nearmap North America General Manager, Tony Agresta. "Combining our industry leading aerial imagery with UP42's extensive database, will ensure customers are getting the most up-to-date and reliable data as they make business decisions."

UP42 customers will find the Nearmap Vertical images, as well as Digital Surface Models and 3D data sets, deliver consistent spatial detail, confident measurements, and frequent updates for any geospatial application. The following use cases will be among the most beneficial for UP42 customers using Nearmap data:

Energy and Water Utilities – The Vertical imagery provides the refresh rate and spatial detail to continually monitor the condition of utility infrastructure and surrounding environments. The centimeter-level resolution and vertical measurements that can be taken from the imagery also serve the needs of 5G wireless network planners.

Construction – Nearmap data is used extensively by Architecture, Engineering and Construction (AEC) firms to select suitable construction locations and to monitor the progress of major building projects underway, especially in remote locales.

Local Government – City managers can rely on frequently refreshed Nearmap orthoimage products to monitor municipal assets, while Urban Planners use the data to predict growth and to accurately plan when and where new infrastructure should be built to keep pace with development.

To request a Nearmap image search or to place an order, please contact an UP42 technical expert. They are also available to assist customers in selecting other geospatial data sets and processing tools to fully leverage the value of Nearmap imagery in specific end-user applications. To learn more, please visit this link: https://up42.com/goingup/nearmap.

EVENTS

The URISA GIS Leadership Academy includes interactive exercises, small-group discussions, team-building activities, and opportunities to delve into topics in a way you cannot do at a large conference. Participation is intentionally limited in order to encourage such interaction.

The Academy will be hosted in-person at these two locations in the coming months:

- Philadelphia, Pennsylvania (August 8-12, 2022)
- Santa Rosa, California (October 31-November 4, 2022)

It will also be presented virtually June 27-July 1, 2022. (It is likely that a second virtual offering will be added in December, based on faculty availability.)

With more than 1,000 graduates over its fifteen year history, the GLA is regularly rated highly by participants. Consider these recent testimonials:

- *"Highly recommend URISA's GLA no matter where you are in your geospatial career or organization. GIS is a disruptive technology to any business organization. From wherever we sit in our organization, we as GIS professionals need to lead this constant change and help our organizations adapt. The GLA gives you these tools and valuable discussions among other GIS professionals." (2021 GLA Minneapolis Graduate)*
- *"The GLA was a great program to help any GIS professional recognize their role as a geospatial leader. One of the best trainings I've participated in." (2021 GLA St. Pete, FL Graduate)*
- *"I cannot say enough about the quality and value of the GLA. I never would have expected to learn so much in 1 week. Though like drinking from the fire hydrant at times, the content was applicable, well thought out, and practical! I will be a better leader, regardless of organization size, because of my experience! Thank you for the opportunity to be a part of it and learn." (2021 Virtual GLA Graduate)*

Learn more at www.urisa.org/education-events/urisa-gis-leadership-academy/.

CALENDAR

- 27 June - 1 July, **URISA GIS Leadership Academy**. For more information, visit www.urisa.org/education-events/urisa-gis-leadership-academy/.
- 8-12 August, **URISA GIS Leadership Academy,** Philadelphia, Pennsylvania. For more information, visit www.urisa.org/education-events/urisa-gis-leadership-academy/.
- 23 September, **ASPRS GeoByte — Allen Coral Atlas: A New Technology for Coral Reef Conservation.** For more information, visit https://www.asprs.org/geobytes.html.
- 3-6 October, **GIS-PRO 2022**, Boise, Idaho. For more information, visit https://www.urisa.org/gis-pro.
- 23-27 October, **Pecora 22**, Denver, Colorado. For more information, visit https://pecora22.org/.
- 31 October - 4 November, **URISA GIS Leadership Academy,** Santa Rosa, California. For more information, visit www.urisa.org/education-events/urisa-gis-leadership-academy/.

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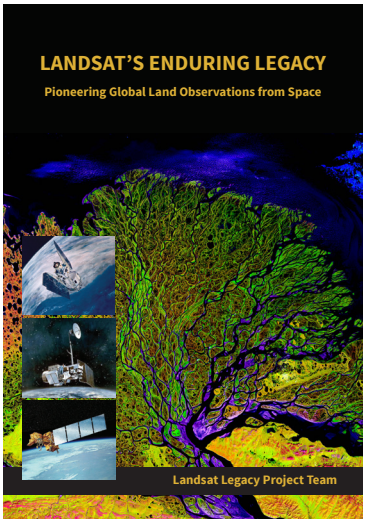

COLUMNS

ANNOUNCEMENTS

DEPARTMENTS

See the Cover Description on Page 356

COVER DESCRIPTION

Picturesque Clouds off Greenland — A few times every spring, the skies over the Labrador Sea fill with row after row of long, parallel bands of cumulus clouds. The magnificent organization of these clouds, known as cloud streets, was on full display when this image was acquired on April 19, 2022.

Captured with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, the image shows cloud streets sweeping over the open water between Labrador, Canada, and southwest Greenland.

The appearance of cloud streets indicates that strong, cold winds were blowing toward the southeast over comparatively warmer water. In springtime, sea ice has already entered the melting season, but there is still plenty of ice over land and sea to produce very cold, dry air. There is also enough open water from which that air can draw moisture and form clouds.

The pattern is the result of the ice-chilled air being warmed by the ocean surface and forming strong currents of upward moving air, or thermals. The moist air rises until it hits a temperature inversion, which acts like a cap and causes the air to roll over and form parallel cylinders of rotating air. On the upper side of these cylinders (the rising air), clouds form. Along the downward side (descending air), skies are clear.

The wide view reveals even more compelling cloud patterns. Notice that the cloud streets are adjacent to an area of vortices off the southeast coast of Greenland. According to Gunilla Svensson, a meteorologist at Stockholm University, those clouds were likely related to a narrow band of high winds known as a "tip jet." A tip jet is thought to be caused by winds that accelerate as they are forced to go around the steep topography of Cape Farewell.

To see the entire image, visit https://earthobservatory.nasa.gov/images/149759/picturesque-clouds-off-greenland.

NASA Earth Observatory images by Joshua Stevens, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview. Story by Kathryn Hansen.

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Correspondence relating to all business and editorial matters pertaining to this and other Society publications should be directed to the American Society for Photogrammetry and Remote Sensing, 8550 United Plaza Boulevard, Suite 1001, Baton Rouge, LA 70809, including inquiries, memberships, subscriptions, changes in address, manuscripts for publication, advertising, back issues, and publications. The telephone number of the Society Headquarters is 301-493-0290; the fax number is 225-408-4422; web address is www.asprs.org.

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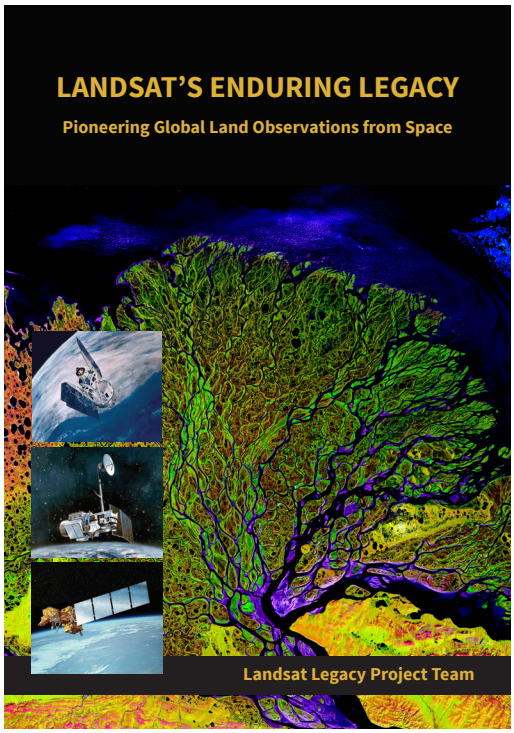

Landsat's Enduring Legacy: Pioneering Global Land Observations from Space

By Samuel N. Goward, Darrel L. Williams, Terry Arvidson, Laura E.P. Rocchio, James R. Irons, Carol A. Russell, and Shaida S. Johnston

Foreword

This book on the evolution of the Landsat program will inform and inspire readers as it reveals the development and worldwide impact of the Landsat series of satellites and sensors that have matured over a half century of technological and scientific progress.

Emerging out of post-World War II research, industry, and engineering, Landsat pioneered the monitoring of Earth's land areas. Landsat, originally named "ERTS" for Earth Resources Technology Satellite, embodied many "firsts" in satellite data collection: first digitally encoded Earth data from a space platform, first imagery of scenes repeated at fixed intervals at the same local solar time, and first terrestrial imaging in several spectral bands with sufficient geometric fidelity to allow meaningful comparison of the responses in those channels. Ingenious users gleaned much from the data, and had the globe set before them. Agricultural inventories, accurate maps, cataloging of geologic lineations, and damage assessments from disasters followed quickly. Gone was the total dependence on individuals who hiked each quadrangle on the ground and eyeballed each planted field, and on aircraft flying limited flight lines. We remember those days with nostalgia but little regret.

The history recounted here is a monument to the armies of dedicated workers from the USGS, NASA, and their partners in other federal agencies, private industry, academia, and international cooperators, who carried on and advocated for the program, and while doing so educated those who managed the federal budget about many aspects of the satellite system. Especially enlightening are the accounts, through anecdotes and other sources, that exhibit the expertise and perseverance over many years of those who designed, operated, maintained, troubleshot, and applied this extraordinary use of space technology. Every individual and organization who has been involved in the Landsat program may be justifiably proud of their contributions in providing broad and deep understanding of the precious nature of Earth's life-sustaining surface, the changes occurring associated with ever-growing population, and the interconnection of global ecosystems, biogeochemical cycles, and life itself.

These efforts have demonstrated the importance of nurturing Earth's natural resources and habitats for the enduring benefit of humankind and other living beings. We hope the leaders and decision-makers of diverse world governments and organizations, and the citizens whom they serve, find this account of the Landsat story instructive and motivational as they face serious issues now and in the future. We were privileged to play our parts in this outstanding program.

~ Virginia T. Norwood, 1979 William T. Pecora Award
~ Vincent V. Salomonson, 1987 William T. Pecora Award

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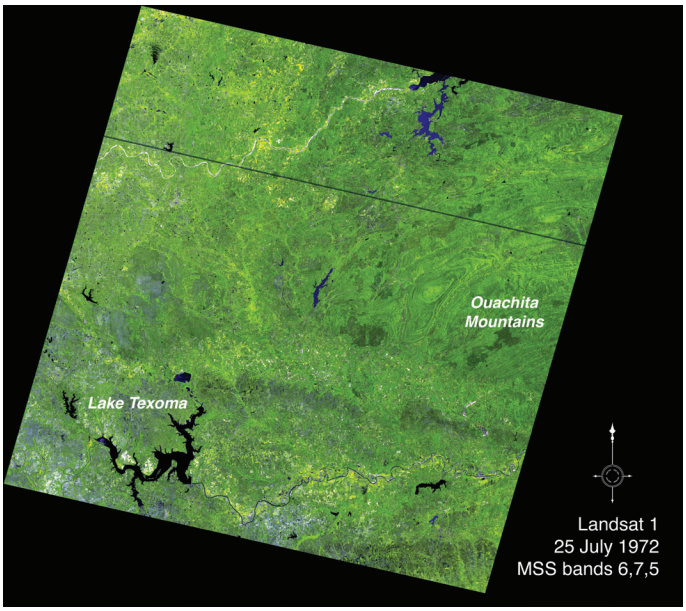

Upon seeing the first Landsat 1 multispectral scanner system (MSS) image, NASA geologist Nicholas Short, who had been unconvinced of the utility of land remote sensing for geology, turned to Len Jaffe, the NASA Deputy Associate Administrator for Space Applications, and said, "Len, I was so wrong about this. I'm not going to eat crow. Not big enough. I'm going to eat raven." Likewise, the well-known USGS cartographer Alden Colvocoresses, known simply as Colvo, who had been cynical about any cartographically accurate data being collected with "a little mirror in space," turned to his colleagues after seeing the MSS imagery and said "Gentlemen, that's a map."

As the world's first digital land-observing satellite program, Landsat missions laid the foundation for modern space-based Earth observation and blazed the trail in the new field of quantitative remote sensing.

A principal legacy of the Landsat program is the nearly half century of global land observation data archived in Sioux Falls, South Dakota, home of the U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center. There simply is no other similar long-term record readily available for local, regional, and global scale scientific research as well as natural resource management. The basic purpose of the Legacy project and the resulting book is to document and explain salient aspects of the first fifty years of Landsat activities and operations, so that current and future generations can comprehend both the qualities and vagaries of the Landsat observation record.

Chasing the mystery of "missing" Landsat data coverage and inspired to capture the far-flung knowledge of Landsat's backstory, the Landsat Legacy Team spent more than 15 years researching, writing, and interviewing a rapidly dwindling population of aging Landsat program veterans. This resulting book chronicles the nearly half-century history of observing Earth's lands with the visionary Landsat satellite series.

In the process of pioneering global land monitoring, Landsat drove innovation in digital imaging technologies and encouraged development of global image data archives. Use of Landsat imagery led to early breakthroughs in assessments of natural resources, particularly in agriculture, forestry, and geology.

The technical remote sensing revolution detailed herein was neither simple nor straightforward. Initial conflicts between the civilian and defense satellite remote sensing domains gave way to the public service vs. commercial enterprise debate concerning how the Landsat program should be administered. The failed attempts to privatize Landsat nearly led to its demise. Only the combined engagement of civilian and defense organizations and users ultimately saved this remarkable program.

With the emergence of 21st century Earth system science and global climate research, the full value of the Landsat concept and its continuous global archive has been recognized.

About the Book's Organization

Chapters One through Five are broken into time periods covering, respectively, the post-World War II era leading up to the launch of the first Landsat, and then roughly the four decades after that. Chapter Six considers the over-arching themes and lessons learned of the Landsat program history. The Epilogue highlights events and developments starting in 2013, following the launch of the Landsat Data Continuity Mission (LDCM)—now Landsat 8. Comprising the back matter are several appendices, a bibliographic essay and bibliography, a list of acronyms and abbreviations, and an index.

Table of Contents

Download the full book as a PDF from ASPRS at https://my.asprs.org/landsat

MAPPINGMATTERS

YOUR QUESTIONS ANSWERED

The layman's perspective on technical theory and practical applications of mapping and GIS

BY Qassim A. Abdullah, PH.D., PLS, CP**

QUESTION:

Question: I'm conducting an experiment to see how different methods of surveying vary when used to estimate volumes. Does ASPRS put out standards of accuracy for using photogrammetry to determine volumes? I'm also trying to determine if there's a way to truly test the accuracy of these data. On another note, to your knowledge, is there a smartphone application that uses photos to determine volume? I know Pix4D has an application for such a thing, but it requires a smartphone with lidar capability, such as the iPhone 12 and 13. I am trying to find one that does not require the lidar capability, only a camera, to estimate volume. What are your thoughts?

Jordan Aikins, Lumos & Associates, Carson City Nevada

Dr. Abdullah: The simple answer to your question about whether ASPRS has a standard for volume computation accuracy is no, we do not have one. However, we are considering developing a standard for 3D modeling and oblique imagery that will touch on the topic you raised. As for volume computations, there are a few parameters that contribute to the quality of volume assessment besides positional accuracy. Those that come to mind are point cloud density and the different methods of modeling terrain, such as the more widely used, polygon-based Regular Triangulated Networks (RTNs) and Triangulated Irregular Networks (TINs), versus options like Voxel-based networks. Terrain modeling and volume computation quality are sensitive to whether the software represents the point cloud as a TIN, a gridded surface or an RTN. If it is an RTN, then you must consider what post spacing that grid needs to be created with. Here, I would like to elaborate on point density, since it is the most important contributor to the quality of modeling terrain. In many instances, users of lidar data for example focus on point cloud accuracy as specified by sensor manufacturers, ignoring an important aspect of the terrain modeling quality: the data density and how it varies according to the terrain smoothness. Figure 1 clearly illustrates this problem. While the point cloud was acquired to a positional vertical accuracy of 10cm, the lack of point density caused the modeling software to estimate the vertical position of Point A to be at Position A', resulting in a vertical error in the digital terrain model (DTM) of 2m or even more depending on the terrain undulation. To remedy this situation and obtain an accurate representation of the terrain, the point cloud needs to be acquired at a higher density. In the case of the terrain in Figure 1, higher point cloud density is the only way to accurately represent the terrain shape. If the terrain contains a high-frequency undulation, using a low-density point cloud results in substantial inaccuracy in the volume estimation no matter what software or modeling algorithms are used. This high-density requirement is not necessary if the terrain does not fluctuate rapidly and is flat or smooth. Totally smooth or flat terrain can be accurately modeled using a point cloud with nominal post spacing (NPS) of a few meters or coarser.

> **"Point density is the most important contributor to the quality of modeling terrain."**

> **"Totally smooth or flat terrain can be accurately modeled using a point cloud with nominal post spacing (NPS) of a few meters or coarser."**

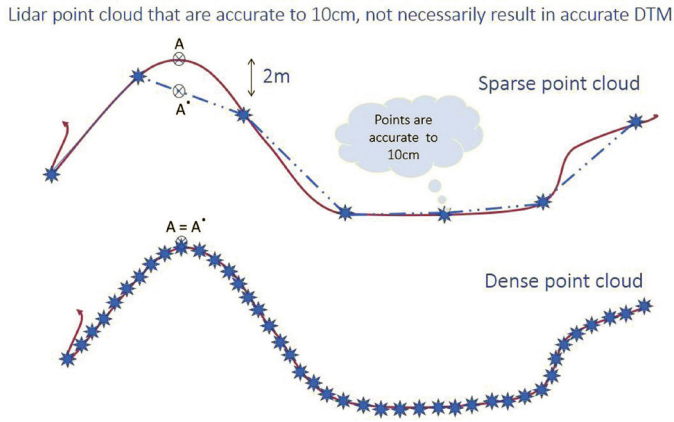

Figure 1: Terrain roughness and point cloud density.

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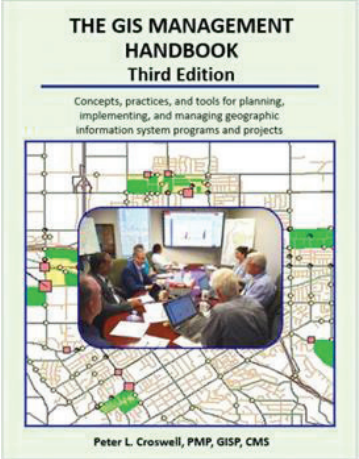
As for processing software, you should be able to do photogrammetric computations in Pix4D using smartphone imagery. I am not sure that you can run Pix4DMapper on a smartphone, but you can import and process imagery acquired by a smartphone into a desktop or cloud processing engine of Pix4DMapper. Using smartphone imagery, Pix4DMapper can generate a point cloud, perform feature removal to create a DTM, compute volume and export contours. Other software on the market, such as SimActive's Correlator3D, Agisoft Metashape, Trimble UASMaster and others, can perform similar processing.

***Dr. Abdullah is Vice President and Chief Scientist at Woolpert, Inc. He is also adjunct professor at Penn State and the University of Maryland Baltimore County. Dr. Abdullah is ASPRS fellow and the recipient of the ASPRS Life Time Achievement Award and the Fairchild Photogrammetric Award.*



The GIS Management Handbook—Concepts, Practices, and Tools for Planning, Implementing, and Managing Geographic Information System Programs and Projects, 3rd Edition.

Peter L. Croswell, PMP, GISP, CMS

2021. Kessey Dewitt Publications, Frankfort Kentucky, in association with URISA. xv+474 pages. ISBN-13: 978-0-9824093-0-5

Paperback: $145 Non-Academic and $60 Academic (with .edu email addresses) plus $10 shipping and handling for U.S. mailing addresses; $55 for Canada; $68 International orders.

Digital Option: 1-Year Access $70 (accessible on up to two devices). Digital Option: 3-Year Access $120 (accessible on up to two devices). (NOTE: the digital version of the book will be available later in 2022.)

Reviewed by Demetrio P. Zourarakis, PhD, GISP, CMS (GIS, RS, Lidar), Adjunct Assistant Professor, Dept. of Plant and Soil Sciences - University of Kentucky, Visiting Professor, College of Agriculture, Communities, and the Sciences.

Now in its third edition, the GIS Management Handbook by Peter Croswell contributes a modernized and welcome version of this well-established and cherished classic. Comprehensive and reflecting the state-of-the-practice, this book has long been among only a handful of texts to deal properly with this vast and complex subject matter. The handbook represents a compendium in which professional managers specializing in GIS programs and projects will find a rich assembly of relevant topics, treated from every foundational and practical angle and perspective.

It is hard to find a weakness in a handbook such as this, as it represents a thorough, exhaustive, and all-encompassing exposition of the principles and applications of the science, technology, and art of management pertaining to GIS programs and projects. Despite the timetable imposed upon the author to develop, write, and publish, some current issues managed to be included in this edition. His book being published in the middle of the COVID-19 pandemic – which is referenced throughout - the author reiterates in several places, such as in *Chapter 2—GIS Program Development* for example, the need to consider remote work (telecommuting or telework) trending as a viable option to be offered to team members.

Understandably, and also due to the timing of the publication, the treatment of a current issue of particular importance in human organizations escaped inclusion in the handbook. Despite that the term *diversity* is amply referenced throughout Chapters 3 and 4, and sections therein, the combined *diversity*, *equity*, and *inclusion* (DEI) aspects of personnel and project management as such did not receive the necessary attention. This absence should not be viewed as a deficiency or a deterrent, but an opportunity to use the handbook—in many ways a virtual version of the author's brain trust—to assist in developing policies geared towards addressing DEI through an enrichment of management practices tailored to each workplace ecosystem. To that end, some salient aspects of inclusiveness and equity are already hinted at in *Chapter 3—GIS Program and Organizational Structure, Governance and Coordination*, and in *Chapter 4—Human Resources for GIS Programs*. Chapter 3 deals with organizational culture impacts on staffing and staff relations with management (e.g., exhibit *3.1—Illustrating Organizational Culture Impact on a GIS Program*). Chapter 4 includes topics regarding staffing and changes in the workforce and workplace (e.g., section *4.2.3—Recruiting and Hiring Staff*, 4.*2.4—Legal and Policy Aspects of Personnel Management*, and *4.2.6—Changes in the Workforce and Workplace*). Also in Chapter 4, section *4.3—Professional Ethics in GIS* and specifically Exhibit *4.4—Professional Ethics Scenarios and Decisions on Conduct*, scenarios of ethical dilemmas are discussed concerning bias and the limits to personal expression while for example, using social media.

The handbook is a consistently solid resource when it comes to providing the fundamentals and examples of ethics applied to the professional practice of GIS and management, and in the management of a workplace and a workforce in general. *Appendix D—Professional Codes of Ethics* cites Chapter 3 "*Respect of the Professional Management Institute (PMI) Code of Ethics and Professional Conduct*," which contains a set of guidelines that may be applicable to the development of DEI

continued on page 364

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GIS Tips & Tricks

Al Karlin, Ph.D. CMS-L, GISP

Confused by Map Scale … Join the Crowd

Readers of this column will recognize one of my mantras… "Never accept the defaults!" Yes, this is another column about default map settings and how to avoid them. This time, I am coupling my mantra to another pet peeve…Map Scale Bars.

Map scale can be a very confusing concept, especially for beginning students in GIS and map making. A "large-scale map" shows a small area and is referenced with a small number, usually 4 or fewer digits in the 1:XXXX ratio notation (where XXXX is the 4-digit number). Likewise, a "small scale map" shows a very large area and is referenced with a large number (five or more digits) in the 1:XX,XXX ratio notation. Then, explaining that the scale is unitless; just referring to whatever units on the map to those same units on the ground, never ceases to confuse students. So…how can a 1:24,000 map be the same as a 1 inch = 2000 foot map? Never mind how a 1:63360 map is the same as a scale of one inch equals a mile!

As a real-life example of how confusing map scale can be, several years ago, I had a field assistant ask me to make a map using USGS DOQQ imagery as a base map (tells you how long ago this was) at a one-to-one scale. You can imagine the baffled look I got when I told the field assistant that with the pixel size of the imagery (1m Ground Sample Distance) that the request for a map showing 360 acres would require 1,456,868 x 36" x 36" sheets of plotter paper, each with a single pixel-color! (We decided at a more reasonable 1:36000 scale.)

Tip 1— So… what is important to remember is that absolute scale is a RATIO of units on the map (the numerator; indicated by the "1") to those same units on the ground (the denominator; indicated by a number greater than 1). As the difference between them increases, you are "zooming-out"; as the difference between them decreases, you are "zooming-in."

Tip 2— Not every map requires a map scale bar. For example, maps designed to show world-wide population trends, or voting trends in the US, really do not need a scale bar (or scale text). The information content of these maps is the important factor, not the ability to make linear (or areal) measurements. (Map projection is a whole different issue.)

Adding a Scale Bar in ArcGIS Pro

Adding a scale bar in ArcGIS Pro (or ArcGIS Desktop) is a pretty easy task. If you have not already done so, insert a Layout tab to your project, choose the Map Frame, click on the Scale Bar to choose a format, all from the ribbon, and click & drag a scale bar on the layout. In the example below (Figure 1), I chose a scale bar in miles (units) and inserted it onto my layout. Just dragging the scalebar by the handles to increase/decrease the size, changes the values and increments. As in Figure 1, the default scalebar indicates that some distance (not an inch or any other unit measure) on the map is 0.025 units (miles) on the ground.

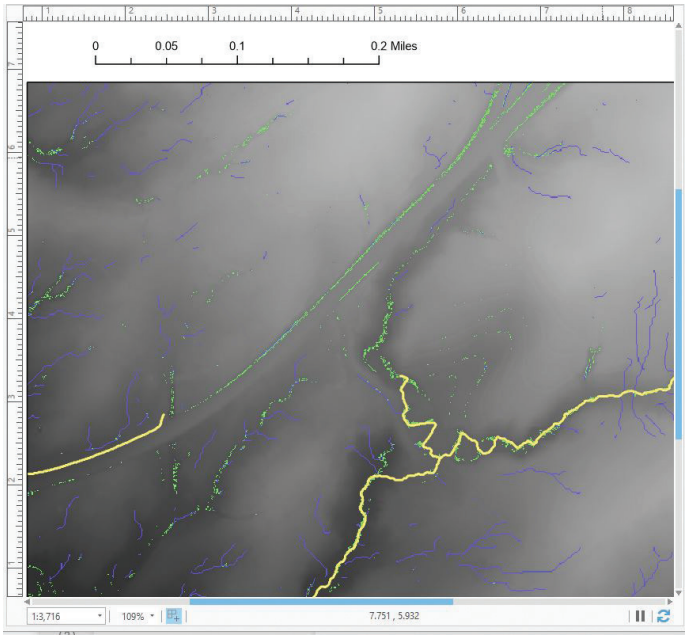

Figure 1. Map showing default scale bar.

To make this scalebar truly meaningful, it really should relate 1" on the map, for the English (Imperial) System, to some number of inches (or in this case feet or miles) on the ground. If we want to use the Metric System, then we would be relating centimeters (cm) on the map to related

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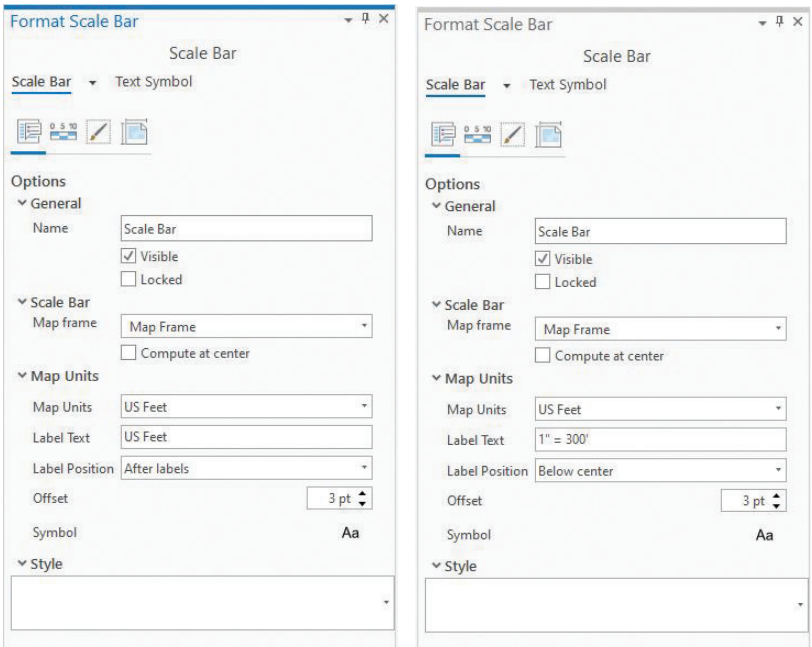

Figure 2. (A) Setting the Scale Bar units. (B) Setting the Scale Bar Label Text and Position.

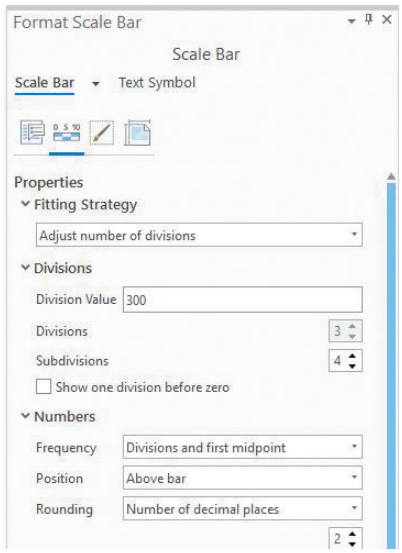

Figure 3. Setting the Divisions and Division Values.

Metric units (meters or kilometers) on the ground. Remember, whatever the case…never accept the defaults!

Managing a Scale Bar in ArcGIS Pro

1. To manage the scale bar, start by managing the scale of the map. In Figure 1, the Layout is reporting a scale of 1:3,716 (see lower left corner in Figure 1). With a little quick mathematics and knowing that there are 12 inches (") in a US Foot ('), a map scale of 1:3600 (a multiple of 12) would be a convenient 1" = 300' relative scale, and very close to the 3,716 default map scale. So, first set the map scale to 3600 by manually changing the value in the scale box. This will change the content extents of the map, so adjustments may be needed to accommodate the 1:3600 scale. Of course, if you need to adjust the map manually on the layout to zoom in or out, you will need to re-calculate/adjust the scale to some multiple of 12.

2. Next, double-click on the scale bar (or open the scale bar properties from the Contents window, or use the Scale Bar | Design tab as in Figure 5 below) to manage the default scale bar. Because we are looking at a "large scale map", and the units could be better expressed in US Feet rather than miles, on the Scale Bar Options tab (Figure 2A, left), change the Map Units and Label Text to US Feet. This is also a good time to alter the Label Text and position (Figure 2B, right). Edit the Label Text to 1" = 300' and use the position dropdown to move it to "Below center". This will put the scale text under the center of the scale bar as in Figure 4.

3. Then move to the Scale Bar Properties (Figure 3) and change the Fitting Strategy to "Adjust number of Divisions and set the division to 300. The scale bar changed to incorporate the user-specified modifications (Figure 4) to show 1" = 300'. Note that there are several additional customizations on the Properties menu. Now when this map is printed, or viewed at 100% as a PDF, one inch on the paper (or screen) will be the distance between 0 and 300 on the scale bar.

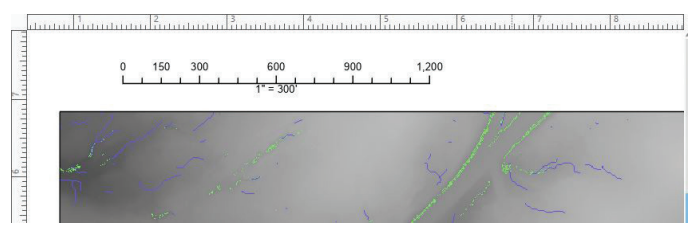

Figure 4. Scale Bar and Text Label adjusted to user-specified units.

4. For a reality check, and to make sure that you really have a map scale of 1:3600 (1" = 300'), insert the scale text as Dynamic Text. The Dynamic Text | Scale Text is located on the ribbon (Figure 5). Click on the Dynamic Text icon, select the scale text and click & drag a scale text box on the layout. This value is the computer-generated map scale and it should agree with the manual settings (i.e., 1:3600). As the relative scale (1" = 300') has been added under the scale bar, the dynamic text can be removed.

As with all GIS software, there are multiple ways to accomplish any task. The scale bar management described above can also be accomplished by double-clicking on the

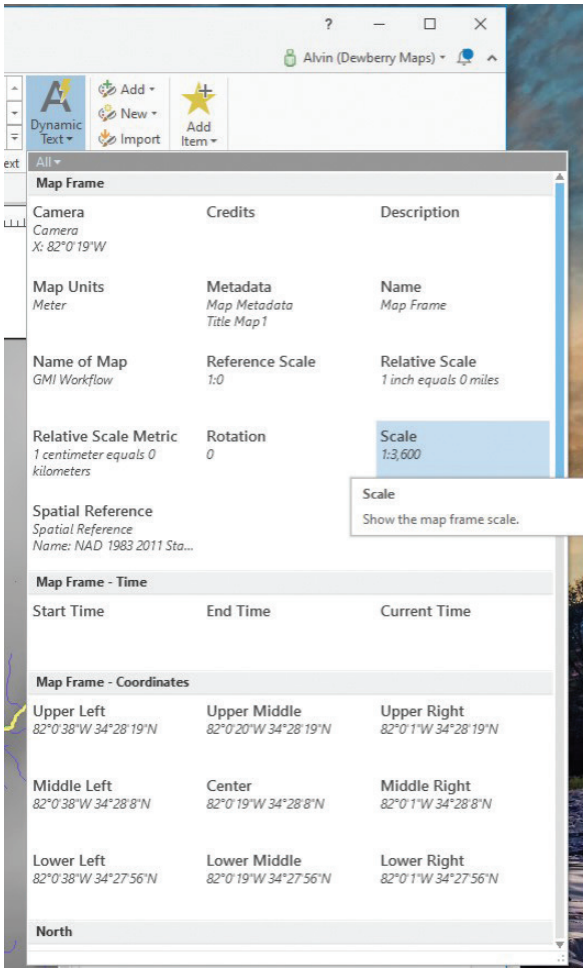

Figure 5. Inserting the Map Scale as Dynamic Text.

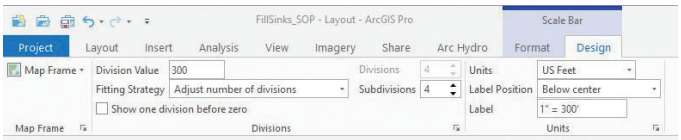

Figure 6. The Scale Bar | Design Tab on the ribbon is an alternative menu for managing the scale bar.

Scale Bar, and using the Design Tab on the ribbon (Figure 6) to manage the default settings.

And finally, there are multiple YouTube videos addressing scale and scale bar management, and of course, Google knows everything. Just google something like, "setting the scale bar in …".

Send your questions, comments, and tips to GISTT@ASPRS.org.

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Book Review, *continued from page 361*

policies. Quite easily, an addendum addressing training and professional development focusing on DEI for employees and managers could be added to *Appendix C—Descriptions of Sources and Approaches for Training and Professional Development* or included as a new appendix either in future editions or as a supplement to this edition.

Throughout its Introduction, ten chapters and five appendices, the book sports not only a plethora of references to published literature and online sources of a diverse nature, but also an abundance of illustrative materials, totaling forty-five tables, fifty-three figures, and twenty-six exhibits. Included with a book purchase is a comprehensive and high-quality set of supplemental digital materials—a set of documents, spreadsheets, and graphics that provide real-world examples and tools on topics covered in the book.

Again, as with all substantial volumes, the physical dimensions of the tome are imposing (weighing over three pounds and being one-and-a-half inches thick), compromising its portability. Thus, my recommendation is to procure the digital version of the book. At the time of this writing, the existing information on how to procure a digital version of the book is described as follows. URISA is now offering a digital version using a secure PDF file access technology provided by FileOpen Systems. By ordering this digital version (www.urisa.org/gismanagementhandbook) the purchaser will receive a subscription to access the book on selected computers, with the option to purchase a 1-year or 3-year subscription. After the order and payment information are verified, the purchaser will be set-up as a subscriber. Within three business days, an email with an encrypted PDF file, a username (purchasers email address) and a password will be sent. When this is successfully installed, the purchaser will be able to open the encrypted PDF file and enter a new Username and Password.

The subscription timing starts at the point of first access (first time opening the encrypted PDF file on a computer). In order to open the file, a FileOpen plugin for Adobe Reader or Acrobat software must be installed on a Windows or Macintosh computer (https://plugin.fileopen.com/all.aspx). After first access, the new username and password will not need to be re-entered. Currently, the digital option is only available on Microsoft Windows or Apple Macintosh computers. In the future (by end of 2022), there will be an option for direct Web-based access (no downloads) which will allow access by any Internet-accessible devices (including tablet computers). An order will allow for opening the digital book on a maximum of two devices. Eventually, digital orders for both the English and Spanish versions will be possible.

To use a term now much in vogue, a deep dive into this authoritative, voluminous, and rare resource will require discipline and dedication on the part of GIS professionals and managers, who will undoubtedly be rewarded with information critical to the success of their program.

Grids & Datums

FEDERAL ISLAMIC REPUBLIC OF THE COMORES

BY Clifford J. Mugnier, CP, CMS, FASPRS

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on the Federal Islamic Republic of the Comores was originally printed in 2004 but contains updates to their coordinate system since then.

According to the Library of Congress Country Studies, the Comoros is an archipelago comprised of Grand Comore (Njazidja), Anjouan (Nzwani), and Mohéli (Mwali). Mahoré (Mayotte) is administered by France but is claimed by the Comoros. The islands are situated in the western Indian Ocean, about midway between the island of Madagascar (*PE&RS*, February 2000) and the coast of East Africa at the northern end of the Mozambique (*PE&RS*, September 1999) Channel. The archipelago has served in past centuries as a stepping stone between the African continent and Madagascar, as a southern out-post for Arab traders operating along the East African coast, and as a center of Islamic culture. The name "Comoros" is derived from the Arabic *kamar* or *kumr*, meaning "moon", although this name was first applied by Arab geographers to Madagascar. In the nineteenth century, Comoros was absorbed into the French overseas empire, but it unilaterally proclaimed independence from France on July 6, 1975. The island republic has since had 19 coups or coup attempts since its independence.

Little is known of the first inhabitants of the archipelago, although a sixth-century settlement has been uncovered on Nzwani by archaeologists. Historians speculated that Indonesian immigrants used the islands as stepping-stones on the way to Madagascar prior to A.D. 1000. Because the Comoros lay at the juncture of African, Malayo-Indonesian, and Arab spheres of influence, the present population reflects a blend of these elements in its physical characteristics, language, culture, social structure, and religion. Local legend cites the first settlement of the archipelago by two families from Arabia after the death of Solomon. Legend also tells of a

Persian king, Hussein ibn Ali, who established a settlement on Comoros around the beginning of the 11th century. Bantu peoples apparently moved to Comoros before the 14th century, principally from the coast of what is now southern Mozambique; on the island of Nzwani they apparently encountered an earlier group of inhabitants, a Malayo-Indonesian people. A number of chieftains bearing African titles established settlements on Njazidja and Nzwani, and by the 15th century they probably had contact with Arab merchants and traders who brought the Islamic faith to the islands. A watershed in the history of the islands was the arrival of the Shirazi Arabs in the 15th and 16th centuries.

The first Europeans to visit the islands were the Portuguese, who landed on Njazidja around 1505. The islands first appear on a European map in 1527, by Portuguese cartographer Diogo Roberos. Dutch 16th century accounts describe the Comoros sultanates as prosperous trade centers with the African coast and Madagascar. Intense competition for this trade, and, increasingly, for European commerce, resulted in constant

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warfare among the sultanates, a situation that persisted until the French occupation. The sultans of Njazidja only occasionally recognized the supremacy of one of their number as *tibe*, or supreme ruler. By the early 17th century, slaves had become Comoros' most important export commodity, although the market for the islands' other products also continued to expand, mainly in response to the growing European presence in the region. To meet this increased demand, the sultans began using slave labor themselves following common practice along the East African coast. Beginning in 1785, the Sakalava of the west coast of Madagascar began slaving raids on Comoros. They captured thousands of inhabitants and carried them off in outrigger canoes to be sold in French-occupied Madagascar, Mauritius, or Réunion to work on the sugar plantations, many of which were owned by French investors. The island of Mahoré, closest of the group to Madagascar, was virtually de-populated. Comoran pleas for aid from the French and the other European powers went unanswered, and the raids ceased only after the Sakalava kingdoms were conquered by the Merina of Madagascar's central highlands. After the Merina conquest, groups of Sakalava and Betsimisaraka peoples left Madagascar and settled on Mahoré and Mwali. Prosperity was restored as Comoran traders again became involved in transporting slaves from the East African coast to Réunion and Madagascar. Dhows carrying slaves brought in huge profits for their investors. On Comoros, it was estimated in 1865 that as much as 40 percent of the population consisted of slaves! For the elite, owning a large number of slaves to perform fieldwork and household service was a mark of status. On the eve of the French occupation, Comoran society consisted of three classes: the elite of the Shirazi sultans and their families, a middle class of free persons or commoners, and a slave class consisting of those who had been brought from the African coast or their descendants. There is a long history of inter-island hostility, reflected in a Comoran saying: "Grand Comore rules, Anjouan works and Mohéli sleeps." The Comoros is slightly larger than 12 times the size of Washington, D.C. The coastline is 340 km, the lowest point is the Indian Ocean (0 m), and the highest point is Mount Kartala (2,360 m),, a volcano that last erupted in 1977.

Datum origin points, thanks to John W. Hager are: "On Ïle Mohéli is Bangoma (east base) at Φ_o = 12° 16′ 55.1″ S, Λ_o = 43° 45′ 03.9″ E, α_o = 247° 02′ 29.544″ to Ditsoni from north, International (ellipsoid), H_o = 2.56 meters. On Ïle d'Anjouan is Chanda at Φ_o = 12º 11′ 06.6″ S, Λ_o = 44º 27′ 24.6″ E, α_o = 144º 25′ 31.84″ to Dziani from north, International (ellipsoid), H_o = 823.8 meters. On Grande Comoro is M'Tsaoueni (north base) at Φ_o =11º 28′ 32.2″ S, Λ_o = 43º 15′ 42.15″ E, α_o = 175º 31′ 53.886″ to Hahaia from north, International (ellipsoid), H_o = 5.47 meters." John W. Hager states, "All of these are from *Archipel des Comores, Répertoire des Coordonnées et Altitudes des Pointes Géodésiques*, Paris, 1974. My intuition is that these were published by I.G.N. and probably taken from Annales Hydrographiques." Thanks to Mark Nettles, the station for the south base is station Domoni and the length of the baseline is 2746.387 m. The IGM Brigade determined 29 fundamental points (first order triangulation), five second order points, and 20 detail points (third order triangulation). All of these islands are on the UTM Grid, thanks to the policy of the French Institut Géographique National since 1950.

Although France administers the Island of Mayotte, the Comores still claim the island. Therefore, I decided to include the island in this column. The 3-parameter datum shift published by I.G.N. from the Combani 1950 Datum to WGS84 is: $\Delta X = -382$ m, $\Delta Y = -59$ m, $\Delta Z = -251$ m. Mayotte is also on the UTM Grid.

Federal Islamic Republic of the Comores Update

The maritime boundary between the Comores and Seychelles was established in a 2012 agreement and extends for 169 nautical miles along a series of geodesic segments that were constructed based on the principle of equidistance. The boundary also includes a tripoint with Tanzania that was created in a separate, trilateral 2012 Agreement. Both of these Agreements have yet to be entered into force.

The configuration of the baselines does depart to an appreciable extent from the general configuration of the archipelago due to the use of baseline point B on Banc Vailheu. Banc Vailheu is more than 10 nm from the closest point on the island of Grand Comore. None of the baselines appear to be drawn using low tide elevations. The baselines are not drawn in a way that would cut off from the high seas or EEZ the territorial sea of another State (except France; see below regarding Mayotte). In conclusion, the archipelagic baseline system of Comoros does not appear to be consistent with the LOS (Law of the Sea – Ed) Convention. Baseline point B on Banc Vailheu, a submerged feature, is not consistent with either (specifying that the baselines join the outermost points of the outermost islands and drying reefs of the archipelago) or (requiring that the baselines not depart from the general configuration of the archipelago). Finally, as noted above, the sovereignty of Mayotte is disputed between Comoros and France. Mayotte is administered as a Department and region of France. Six of the 13 baseline points in Comoros' archipelagic baseline system are used to enclose Mayotte. France has protested this use of baseline points on Mayotte as "not compatible with the status of Mayotte and . . . without legal effect." In December 2013, by Decree No. 2013-1177, France promulgated baselines, including straight baselines and closing lines, from which the territorial sea of Mayotte is measured.

This column was previously published in *PE&RS*.

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STUDENT ADVISORY COUNCIL

Signatures

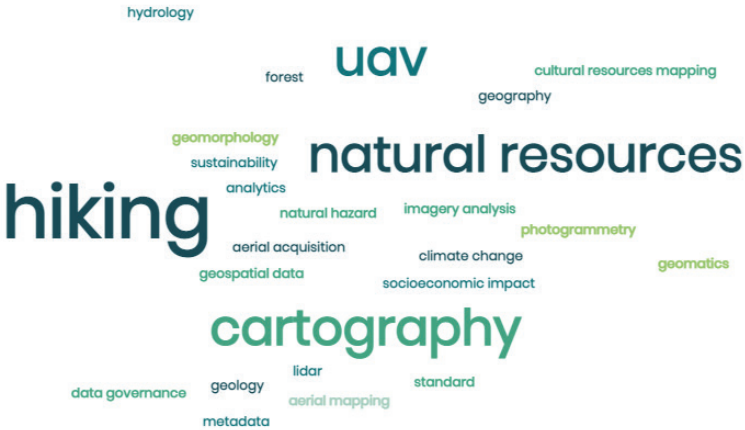
FEATURING THE ASPRS SAC MENTOR-MENTEE PROGRAM PAIRS

The ASPRS SAC Mentor-Mentee program in action! We are excited to feature our mentor-mentee pairs and their journey so far.

Mentor	Mentee
Ryan Bowe Sustaining Member Council Chair and Vice-Chair for INCITS GIS Committee Phase Manager at Woolpert	Pamela Rodriguez Murray State University Chapter President
Lorraine Amanda ASPRS-President Elect Aerial Mapping Project Manager, Towill.Inc..	Mubashir Ali Arid Agriculture University, Rawalpindi
Melissa Martin Phase Manager at Woolpert	Ali Alruzuq Education and Professional Networking Councilor, ASPRS SAC Graduate Student, University of Florida
Abishek Poudel Doctoral Candidate, SUNY ESF Graduate Teaching Assistant, SUNY ESF	Jeronimo Roldan Architectural Historian and Planner Portland State University and University of Oregon
Matthew LaLuzerne Licensed Surveyor, Florida, President of ASPRS- FL Region Strategic Growth Director	Ismaila Olaniyi Graduate Student, Purdue University
Tim Bohn Vice President – Business Development, Surdex Experienced Photogrammetrist	Chukwuma Okolie Doctoral Candidate, University of Cape Town Lecturer, University of Lagos

We are delighted that our mentor and mentee pairs are from a variety of backgrounds and have a spectrum of interests. From UAV to Lidar…forests to effects of climate change, the figure to the right shows the range of interests in technology and application. They also shared general interest such as reading and hiking/travelling.

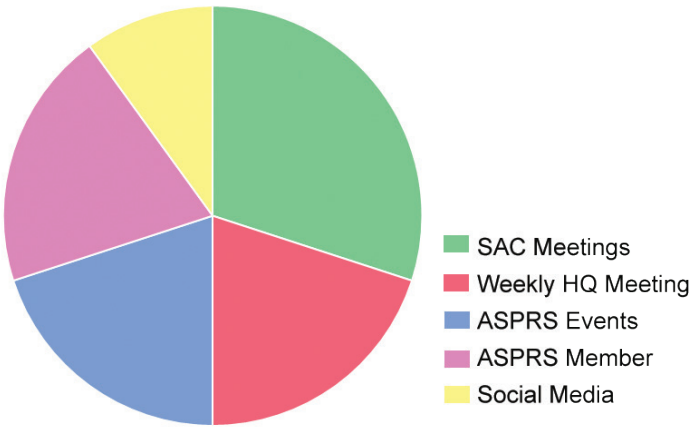
For this special edition of SAC Signatures, the SAC team reached out to our mentor-mentee pairs and asked them about their experience with the program so far and some general interest questions. There responses will help us in the continuation of this program.



How did you hear about the mentor-mentee program?

The SAC worked on the program for more than a year before it's launch. It was important to know how our mentor-mentee pairs learned about the program. The responses can be categorized as shown in the pie-chart:

- ASPRS SAC Meetings
- ASPRS Weekly HQ Meetings
- ASPRS events
- Through ASPRS members
- Social media



As can be seen, most of the responses talk about ASPRS directly; with SAC having a huge part in spreading the word about the program. We would like to show our appreciation of the efforts of our past chair, Youssef Kaddoura and our current chair, Lauren McKinney. Both worked tirelessly to make this program a success. However, the reach beyond ASPRS members is very low. Improving the program visibility beyond ASPRS membership is one of our future goals.

Why did you choose to become a part of the mentor-mentee program?

Although the field and level of expertise for all of our mentors and mentees varies a lot, the responses to this question were quite similar.

From Mentors—There is no doubt that there is not a replacement for a good mentor in our lives. All of our mentors mentioned this in their response saying that they want to give back to the society in the same way they were guided.

From Mentees—The mentees were interested in industry life and the possible choices of career paths after their respective degrees.

What are your expectations from this program?

The responses for this question were also quite similar.

From Mentors—The expectations about our mentor-mentee program from our mentors' point of view can be summarized as follows:

- Interested in building a long-lasting relationship with their mentee
- Share their knowledge and experience of field
- Create a mutually beneficial environment and learn from each other
- Cherishing the time spent together as everyone has a busy schedule

From Mentees—The expectations about our mentor-mentee program from our mentees' point of view can be summarized as follows:

- Be more knowledgeable about the industry
- Develop their competencies and skills
- Learn new skills as per industry's requirements
- Preparation for next career move

How is the program so far?

We are overwhelmed by the responses to this question as this program not only gives career advice, but builds a relationship between the mentor and the mentee allowing for mentors to know their mentees on a personal level and impart life-long changes. Also, it is great to hear that the meetings are more like a conversation and both parties are learning from each other, which is important to continue the cycle of illumination.

Our heart-felt gratitude to all our mentor-mentee pairs for their valuable responses

Are you interested in participating in SAC activities...

- Join us every other Thursday from 10-11 am PST!
- Join us via this zoom link https://tinyurl.com/SACASPRSMeeting

Correction for May 2022 Signature Page

Last month's SAC Signatures incorrectly stated that the Murray State University ASPRS student chapter was "relatively new," although the student chapter has been active since 1991. The faculty advisor for this chapter is Dr. Haluk Cetin, professor of Earth and Environmental Sciences and director of Hyperspectral Laboratory and KentuckyView. He, an ASPRS Fellow, has served as faculty advisor for this chapter since 1999 and served in several capacities at the national level including coordinating student volunteers at national ASPRS conferences.

Also, the current listing of chapter members given did not include the following student members: Dylan Smith, Matt Meyer, Amber Harland-Bennett, Clint Cornelison, Devin Richards, Lacy Risner, Rachel Stuckey, Bryan Floyd, Matthew Owen, and Ash Medlock. We appreciate the alumni of this program that continue to participate, build up and support the work of the chapter and the society and we thank all of the current students for their hard work!

NEW ASPRS MEMBERS

ASPRS would like to welcome the following new members!

Michael Selorm Agbozo
Daniel Bidot
Alexis Bundrick
Evan Carlson
Sean P. Conway
Carlos Femmer
Ushus Hermanson
Victor C. Igwe
Jennifer Klich
Hans Knoepfel
Ron Leach
Dong Won Lee
Adetomiwa Odunayo Maselugbo
Amanda J. Miner
Jesse Morgan, II
Patrick O'Brien
Herman Serrato
Karen Shank
David Smith
Rosendo Hermogenes Villareal

FOR MORE INFORMATION ON ASPRS MEMBERSHIP, VISIT
HTTP://WWW.ASPRS.ORG/JOIN-NOW

ASPRS ANNOUNCES UPCOMING GEOBYTES!

2022 Update of the USDoL Geospatial Technology Competency Model (GTCM)

Presented by Dr. Rodney D. Jackson, *Special Operations School of Information Technology (SOSIT)*
June 3rd

Allen Coral Atlas: A New Technology for Coral Reef Conservation

Presented by Brianna Bambic, N*ational Geographic Society and Arizona State University*
September 23rd

For complete details and to register, visit https://www.asprs.org/geobytes.html.

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Lake Water Footprint Determination Using Linear Clustering-Based Algorithm and Lake Water Changes in the Tibetan Plateau from 2002 to 2020

Gang Qiao and Hongwei Li

Abstract

Satellite altimetry is an effective technique for monitoring water level changes in inland lakes in remote areas, such as the Tibetan Plateau. Lake water footprint (LWF) determination from tracks of satellite altimetry data is a preliminary step for generating lake water level sequences. However, the traditional method of LWF determination using accurate lake boundaries extracted from remote sensing images is laborious, and the images do not always exist. Another method dedicated to a single satellite altimeter sensor, i.e., physical parameter-based algorithm has been designed, but this method sometimes fails when data are influenced by surroundings such as wetlands or glaciers. To overcome these problems, we present a novel linear clustering-based approach for LWF determination to generate a time series of lake water levels by using multi-mission satellite altimetry data sets over typical lakes of the Tibetan Plateau. Our method projects all footprints onto two matrices. This approach is then illustrated using Ice, Cloud, and land Elevation Satellite, Environmental Satellite, and CryoSat-2 altimetry data sets for four typical lakes in the Tibetan Plateau. Among all the methods, our method performs best in terms of accuracy. Finally, the time series lake water levels of 179 lakes in the Tibetan Plateau were extracted using our method. The results indicate that from 2002 to 2020, the average water level of most lakes increased by 0.167 ± 0.155 m/a, whereas a decreasing trend of 0.066 ± 0.047 m/a was observed in the Yarlung Zangbo river basin. The different precipitation conditions in the inner basin and the Yarlung Zangbo river basin are suggested to be the major reasons for the opposite trends. The proposed method performs well for Tibetan lakes with planar water stages and small seasonal fluctuations but is not applicable for lakes with other conditions, which requires further study.

Introduction

Lake water level is an important indicator used in water research and management, especially in the Tibetan Plateau (TP). Regular, accurate monitoring of lake water levels is essential for water resource management and ecosystem services (Tong *et al.* 2016). Regional analysis of lake water level variations over a long period is fundamental to advancing the understanding of the impact of climate change and human activities on the water resources in the TP (Crétaux *et al.* 2011; Jiang *et al.* 2017; Qiao *et al.* 2019; Zhang *et al.* 2020).

The traditional method for lake water level determination is on-site measurement by establishing hydrometric stations. The accuracy of the field-measured lake water level is high, and the observation is continuous in time (Tong *et al.* 2016; Furnans and Austin 2007). However, because of the remoteness, high altitude, thin atmosphere, and harsh weather conditions in the TP, these types of surveys are costly and arduous. Furthermore, the level gauges are easily destroyed by lake ice in winter (Zhang *et al.* 2011). Currently, only the water levels of a few large lakes in the TP are monitored by field surveys; for example, Qinghai Lake and Nam Co (Zhang *et al.* 2011). For most lakes in the TP, field surveys are impractical.

With the development of satellite altimetry and remote sensing technology, researchers have studied the possibility of using satellite altimetry data over continental waters since the late 1970s (Birkett *et al.* 2011). Since 2010, monitoring the water level changes on a large spatiotemporal scale using multi-mission altimetry (including laser altimetry and radar altimetry) and remotely sensed images has been possible (Kropácek *et al.* 2012; Song *et al.* 2013; Gao *et al.* 2013; Zhou *et al.* 2019; Jiang *et al.* 2017; Zhang *et al.* 2019; Zhan *et al.* 2020). However, lake water footprints (LWFs), which represent the altimeter footprints over the surface water of the lakes, must be determined before conducting water level change analysis (Wang *et al.* 2012). The most commonly used method for determining LWFs is based on overlay analysis with accurate lake boundaries derived from images obtained using remote sensors, such as the moderate resolution imaging spectroradiometer (Tong *et al.* 2016; Phan *et al.* 2012; Zhang *et al.* 2019) or Landsat (Gao *et al.* 2013). Generally, the size and shape of a lake in the TP vary over time because of factors such as precipitation, evaporation, and glacier melting (Lei *et al.* 2019). Thus, temporal consistency in satellite imagery and altimetry tracks is required (Zhang *et al.* 2011). When analyzing long time series, many simultaneous remote sensing images and corresponding lake boundary extraction processes are required, resulting in a substantial workload. Moreover, due to the limited spatial coverage of optical images caused by fixed satellite tracks and cloud cover during the rainy season, obtaining the desired accurate lake boundary series is difficult. One alternative is to extract the LWFs within a small region of the lake far away from the boundary to ensure the correctness of the lake water level and that the footprints are within the lake (Tong *et al.* 2016). However, in this case, only a part of the LWFs is obtainable, which may reduce the accuracy with respect to the estimation of the lake water level. Moreover, for some small lakes with sparse footprints, this method may not be applicable because of the paucity of footprints.

Some algorithms use certain characteristics from satellite altimetry footprints to reduce the dependency on optical remote sensing images. For example, Shu *et al.* (2020) used Sentinel-3 Synthetic Aperture Radar (SAR) altimetry waveform retracking algorithms to derive temporally consistent water levels over ice-covered lakes. Song *et al.* (2015) used a binary water mask at a resolution of 30 m to identify *Ice, Cloud, and land Elevation Satellite* (*ICESat*) and *CryoSat-2* footprints.

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Classifying and Georeferencing Indoor Point Clouds with ArcGIS

Jason R. Parent, Chandi Witharana, and Michael Bradley

Abstract

This study aimed to develop and apply a manual procedure for classifying and georeferencing indoor point clouds that we created using Paracosm's PX-80 handheld three-dimensional laser scanner. We collected data for 11 buildings in Connecticut, USA and focused on classifying features-of-interest to public safety personnel (i.e., doors, windows, fire alarms, etc.). ArcGIS Desktop was used to manually digitize features that were easily identified in the point cloud and Paracosm's Retrace was used to digitize small features for which imagery was needed for identification. We developed several tools in Python to facilitate point cloud classification and georeferencing. The procedure allowed accurate mapping of features as small as a sprinkler head. Point cloud classification and georeferencing for a 14 000 m^2 building took 20–40 hours, depending on building characteristics and the types of features mapped. The methods can be applied in mapping a wide variety of features in indoor or outdoor environments.

Introduction

Maps of building interiors provide critical information that allows public safety personnel to pre-plan responses to emergencies, building managers to efficiently manage their facilities, and visitors to find their destinations. Accurate building maps are key for indoor navigation and tracking systems that improve the safety and effectiveness of first responders, as well as to improve convenience for visitors to public buildings (Kunhoth *et al.* 2020). However, accurate "as-built" floor plans that are suitable for current and future needs are not available for many buildings.

Efforts to map indoor environments face some unique challenges caused by limited sight lines, rapid changes in elevation (i.e., stairs), the inability to use global navigation satellite systems (GNSS), and the inability to use mechanized platforms for carrying remote sensing instruments. Indoor mapping systems must be highly mobile for rapid data collection and avoiding blind spots. The systems must also be compact and lightweight enough to be carried comfortably by a human for prolonged periods of time. Light detection and ranging (lidar) scanners create point clouds which can represent features in three-dimensional (3D) space. The recent emergence of handheld lidar scanners provides a practical solution to indoor mapping by combining lidar with high mobility. These scanners use inertial mapping units (IMU) with simultaneous localization and mapping (SLAM) algorithms (Droeschel and Behnk 2018; Diosi and Kleeman 2005; Thrun *et al.* 2004; Castellanos *et al.* 1998) to generate point cloud data as the unit is carried through the building. These scanners also typically integrate a wide angle or spherical red, green, blue (RGB) camera to collect images simultaneously with the lidar data and which can be used to colorize the point cloud to aid feature identification.

Lidar-based systems are rapidly advancing to improve data collection capabilities; however, there are no established procedures for managing and classifying indoor point cloud data or extracting features-of-interest for indoor environments. Software that is commonly used in geospatial analysis and remote sensing focuses on classification and feature extraction from data that represent outdoor environments. These software tend to be poorly suited to the massive sizes and unique characteristics of point cloud data sets created for indoor environments.

Handheld lidar systems do not have GNSS capabilities because they tend to be used indoors where there is no satellite reception. Thus, raw point clouds from handheld systems are not associated with a global coordinate system and must be georeferenced to be used with other geospatial data or with a navigation system. The lack of GNSS also makes the IMU of handheld scanners prone to "drift" as small errors accumulate over the duration of the scan. To minimize drift, the recommended scan durations for handheld scanners are limited. Paracosm, for example, recommends limiting scans to a maximum duration of 20–30 minutes for their PX-80 system (Paracosm 2018).[1] The time limits make it necessary to collect data for larger buildings in multiple scans. Because the individual scans are not georeferenced, they must be co-registered to each other to create a complete point cloud for the building. To our knowledge, co-registration of adjoining point clouds is primarily a manual process for handheld lidar scanners. However, auto-registration capabilities are now becoming features of tripod-mounted scanners, such as Trimble's X7.

Open-source software, such as Cloud Compare (Cloud Compare 2020), have capabilities for georeferencing and co-registering point clouds. To georeference a point cloud, surveyed ground control points are input into the software and manually associated with the corresponding features in the point cloud. The point cloud is then rotated and translated to align the associated features with the ground control points. Once a point cloud is georeferenced, it can be used as a reference to co-register adjoining point clouds. In Cloud Compare, a point cloud is co-registered by manually rotating and shifting the data set until it is roughly aligned to the reference point cloud. After rough alignment, a fine-alignment algorithm can be run to more precisely align the point cloud based on features shared by the overlapping portion of the reference point cloud.

This research aims to develop techniques for classifying and georeferencing indoor lidar point clouds to map features-of-interest. We present an efficient manual process based on the Environmental Systems Research Institute's (ESRI) ArcGIS Desktop and Paracosm's Retrace software along with custom tools developed in Python. The process combines the advantages of using imagery for feature identification with the precise positioning provided by the point cloud. We focus on mapping features-of-interest to first responders including walls, doors, windows, fire alarms, sprinkler heads, etc. The procedure and tools we developed will help establish effective methods of classifying point clouds and mapping indoor environments. In addition, the data we created will be useful for training and validating automated

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1. Paracosm was an Occipital Company (https://occipital.com) that was closed in 2021.

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Towards Automated/Semiautomated Extraction of Faults from Lidar Data

Paul A. Pope, Brandon M. Crawford, Anita F. Lavadie-Bulnes, Emily S. Schultz-Fellenz, Damien M. Milazzo, Kurt C. Solander, and Carl J. Talsma

Abstract

The Pajarito fault system is a complex zone of deformation and a seismically active region nestled within the Rio Grande rift in north-central New Mexico. Numerous laterally discontinuous faults and associated folds and fractures interact in a manner that has important implications for seismic hazards and risk mitigation. Previous efforts have established a foundation for the location of lineaments and structures in the Pajarito fault system; however, ensuring the completeness of the current lineament mapping is required for identifying areas for field validation, evaluating the potential for future seismic activity, and better understanding fault interaction. Assistance with this fault-mapping task via automated or semiautomated techniques as applied to lidar data over a large area of interest is highly desirable. A proof-of-concept processing flow which transforms lidar point-cloud data into a raster of surficial fault candidates is described and illustrated herein. These initial results hold great promise toward achieving our ultimate goal.

Introduction

The Pajarito fault system (PFS), located on and adjacent to the Pajarito Plateau in north-central New Mexico, is a seismically active region suspected to be the current active western margin of the Rio Grande rift (Figure 1; Griggs 1964; Smith *et al.* 1970; Kelley 1979; Gardner and House 1987). The PFS is a complex zone of deformation comprising numerous en echelon laterally discontinuous normal faults, with associated folds and fracture zones (e.g., Gardner *et al.* 1986, 1999; Wong *et al.* 1995; Olig *et al.* 1996; Lewis *et al.* 2002, 2009; Reneau *et al.* 2002; McCalpin 2005). The PFS has had activity within the Holocene (events more recent than 11 000 years ago; McCalpin 2005; Lewis *et al.* 2009; Lettis *et al.* 2019), with an estimated slip rate of <0.1 mm per year (Golombek *et al.* 1983; Olig *et al.* 1996; Koning *et al.* 2013; Ricketts *et al.* 2014; Crawford *et al.* 2019). These faults, folds, and fractures propagate and interact in a complex manner that, while not fully understood, has important implications for seismic hazards and risk mitigation for critical infrastructure in northern New Mexico. Additionally, the spatial position and along-strike length of these individual fault segments are major components in estimating the potential rupture length of the system, which directly feeds estimates of the maximum rupture magnitude for the region (compare Wells and Coppersmith 1994).

Previous efforts have established a foundation for identifying, understanding, and interpreting the location of the lineaments and structures of the PFS. These previous studies include a combination of aerial photographic and topographic analysis, traditional geologic and structural mapping (Gardner *et al.* 1999, 2001; Lewis *et al.* 2002, 2009; Reneau *et al.* 2002; Lavine, Lewis *et al.* 2003), detailed understanding of local geologic units and contact relationships (compare Broxton and Reneau 1995), and high-resolution geodetic surveying methods (Lavine, Gardner and Reneau 2003; Lewis *et al.* 2009). Within some areas of the PFS, previous investigations have used conspicuous topographic changes created on the land surface by major fault segments within the system to identify fault locations. Part of this previous work included manual interpretation of lidar data (circa 2000) to detect and hand-trace suspected faults, highlighted as lineaments cutting the landscape, which are of importance to the structural characterization of the PFS (Wong *et al.* 1995; Olig *et al.* 1996; Carey and Cole 2002; Lewis *et al.* 2009). However, lineament identification alone does not mean a fault is present at a site, and not all faults within the PFS have conspicuous topographic expression in simple digital-elevation-model (DEM) analyses alone. Ensuring the completeness and validity of lineament mapping, confirming through field investigations whether lineaments are surface expressions of faults, and extending the mapping coverage to the north and south of the central PP, is required both to improve the understanding of the PFS and its potential for future

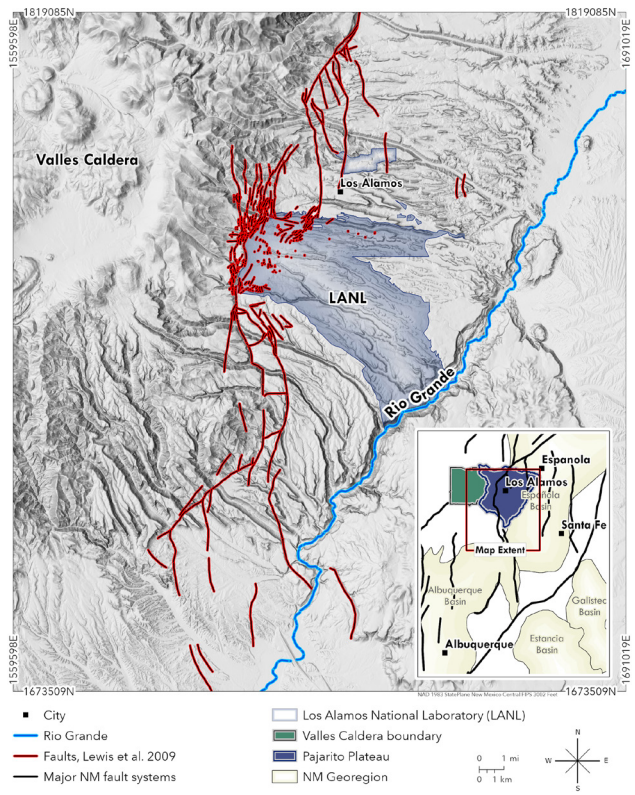

Figure 1. The Pajarito Plateau and the surrounding region, with previously mapped faults of the Pajarito fault system overlaid (pink lines; Lewis *et al.* 2009).

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Feature-Based Convolutional Neural Network for Very-High-Resolution Urban Imagery Classification

Guoming Li, Li Tan, Xin Liu, and Aike Kan

Abstract

In the process of manual image interpretation, the use of a combination of spectral and spatial features can aid in more accurately classifying urban land coverage. In this study, to simulate this procedure, we use two concurrent convolutional neural networks (CNNs) with two scales of input to represent fields of view corresponding to object detail and the related information among objects. In our approach, the results derived from every convolution process are retained and stacked together at the end of the convolution process. Thus, not only are the spectral and spatial features combined, but all the scales of spatial features are also considered. When applied to very-high-resolution remote sensing images, our proposed model with its feature-based CNN achieves a noticeable improvement over other state-of-the-art methods, which helps to assess the urban environment to some extent. In addition, we show that the digital surface model features, either in image form or in numerical characteristic form, can improve the overall accuracy rate of current structures.

Introduction

The field of remote sensing finds extensive use in diverse disciplines ranging from geography to military applications (Gao 1996; Justice *et al.* 1998; Briottet *et al.* 2006; Chen *et al.* 2006; Dalponte *et al.* 2012; Shao *et al.* 2020e, 2020c; Zhang *et al.* 2021). One very important aspect of remote sensing image application is its processing. Classification, identification, and segmentation are the three main tasks in the processing of remote sensing images. Their results are the preconditions required to analyze and apply remote sensing images to other fields, such as the assessment of urban development and the ecological environment (Shao *et al.* 2020c, 2020a). In this context, image interpretation generally refers to the manual process carried out to interpret and analyze such images. Using a priori knowledge, one can describe objects in images qualitatively and quantitatively. However, the development of remote sensing platforms has led to the generation of a significantly larger quantity of high-resolution images, which requires automatic classification of them.

Therefore, several machine learning algorithms have been proposed to process remote sensing images more efficiently (Mas and Flores 2008; Quinn *et al.* 2018; Shao *et al.* 2020b), including the support vector machine (SVM) for the identification of multiple crops (An and Yang 2007), neural networks for the detection of forest fires and smoke (Li *et al.* 2015), and the random forest algorithm for the classification of land cover (Rodriguez-Galiano *et al.* 2012). However, these methods do not consider spatial features and cannot properly represent image features, resulting in low classification accuracy.

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Meanwhile, convolutional neural networks (CNNs) (Hinton and Salakhutdinov 2006) are considered as a highly suitable image recognition algorithm (Krizhevsky *et al.* 2012). In this regard, deep learning (DL) algorithms have gradually been applied in different fields (Mohamed *et al.* 2011; Ji *et al.* 2012; Shao *et al.* 2020f), including medicine (Gulshan *et al.* 2016) and astronomy (Flamary 2017; Zhang *et al.* 2018). As an image recognition algorithm, CNNs can help classify images and pictures more accurately, which makes them suitable for processing remote sensing images. Appropriate adjustments to CNNs can classify each pixel in a scene into a certain category so that the remote sensing image can be completely interpreted.

Thus far, classification models based on DL algorithms have been applied to different kinds of remote sensing images (Chen *et al.* 2014; Marmanis *et al.* 2015; Wei *et al.* 2017; Shao *et al.* 2020d; Zhang *et al.* 2020; Zhang and Zhou 2021). Most of these approaches combine spatial and spectral features to improve the model performance. However, compared with other remote sensing images, very-high-resolution (VHR) images contain more detailed spatial information. Furthermore, CNN is a time-consuming algorithm, so it is more difficult and time consuming to use CNN to extract large-scale spatial features in VHR images, let alone extract and combine any other features. In addition, most of the proposed models directly apply well-tuned models or networks (which perform well in image recognition) to remote sensing images, ignoring the differences between common images and remote sensing images.

From the authors' point of view, the most essential aspect of interpreting an image involves the extraction of high-level features and the combination of features at different levels. To solve the problems mentioned above, this article proposes a CNN-based structure with two concurrent convolutional components in which almost all feature maps are retained as different depths of features.

Before the classification process, the minimum unit to be classified must be clearly defined. We remark here that when interpreting a remote sensing image, the human visual system regards similar pixels in a connected area as one basic unit and classifies it entirely rather than classifying every single pixel separately. This process has been applied to the image segmentation process in our proposed model, which can segment images into superpixels according to the RGB values of adjacent pixels.

Since there are two concurrent convolutional components in the proposed model, two different input sets are fed to the algorithm. One is small scale with a superpixel, and the other is large scale with a superpixel and some of its neighbors. The small-scale set contains low-level features, such as spectral and textural features, while the large-scale set contains not only low-level features but also high-level features, such as relative location and cohesion. Moreover, feature maps derived from every convolution layer of the larger input set are saved since they represent different scales of spatial features. These two input sets are fed into two concurrent convolutional layers with different kernels. On stacking the feature maps derived from every convolution

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Conjunctive Use of Landsat-8 OLI and MODIS Data for Delineation of Burned Areas

Syed Azeemuddin and R.S. Dwivedi

Abstract

For regional-level monitoring of burned areas, Moderate Resolution Imaging Spectroradiometer (MODIS) MCD64A1 and MCD45A1 products have been operationally used. However, because of their coarser spatial resolution, such products do not allow for detection of small patches (<50 ha) of burned areas, which are very important for modeling gas emissions. In order to bridge this gap, we undertook a study to evaluate the synergy of MCD64A1 and Landsat-8 Operational Land Imager (OLI) data for delineating burned areas in part of the mountainous terrain of the Himalayas, northern India. The approach involves generating a differenced normalized burn ratio image from Landsat-8 OLI data before and after fire events, refining the burned areas thus delineated using the MCD64A1 burned-area product and field data, and estimating accuracy. An overall mapping accuracy of 90.0% was achieved using Landsat-8 OLI data. Inclusion of the MODIS MCD64A1 burned-area product resulted in marginal improvement in overall accuracy (to 94.0%).

Introduction

Fire results in the formation and deposition of charcoal, or surface charring, accompanied by the transformation of the structure and abundance of vegetation, commonly known as fire scar, as well as partial or complete removal of vegetation canopies. However, the latter part may also be due to other factors such as felling, grazing, wind throw (uprooting of trees), water stress, or pest and disease infestations. Complete combustion of plant materials in the presence of an adequate oxygen supply results in high-intensity fire and lends an ash color to the burned areas, called ash (Cope and Chaloner 1985; Riggan *et al.* 1994). A restricted oxygen supply, on the other hand, results in inefficient combustion of biomass, leading to the development of graphite-rich carbon known as char (Cope and Chaloner 1985). Wildfires have an important effect on vegetation dynamics, biogeochemical cycles, atmospheric chemistry, and the climate. Information on gaseous emissions is required for addressing international initiatives and commitments related to fire emissions, such as the Kyoto Protocol and the agreements at the United Nations Climate Change Conference in Paris, or the United Nations Sendai Framework for Disaster Risk Reduction 2015–2030 (Koutsias and Karteris 1998; Chuvieco *et al.* 2019). Hence timely and precise information on forest fires and wildfires is a prerequisite for rehabilitating their effects and for regional and global-scale estimates of gas and particulate emissions.

Traditional approaches to generating information on burned areas are tedious, time- and labor-intensive, cost-prohibitive, and impractical, especially in inhospitable terrain. Initially, aerial photographs—panchromatic, color, and color infrared photographs—were used to delineate burned areas, which accelerated the process of generating information on them (Sims and Benson 1966; Cochrane 1970). Since the launch of *Landsat-1* in 1972, data from the spaceborne Multispectral Scanner System (MSS) have been used to delineate burned areas. Changes in spectral response patterns that occur after a fire can be a surrogate for delineating burned areas. In fact, spectral characterization of postfire signals was considered by Chuvieco and Congalton (1988) as a stepping-stone for remote sensing of burned areas. When vegetation is burned, there is a drastic reduction in visible to near-infrared (NIR) spectral response patterns with a concomitant increase in the shortwave-infrared (SWIR) and mid-infrared (MIR) surface reflectance (Lentile *et al.* 2006; Miller and Thode 2007). In a pioneering study, Hall *et al.* (1980) used decreasing values in NIR reflectance to estimate burn severities in a temperate forest. Furthermore, the increase in SWIR spectral response patterns after fires was first observed in Mediterranean forests (Chuvieco and Congalton 1988) and later confirmed in savanna ecosystems.

The approach used for generating information on burned areas from spaceborne multispectral data varies depending on the scale and purpose of the assessment. At the local level, high- and moderate-spatial-resolution (<100 m) data (Silva *et al.* 2005; Bastarrika *et al.* 2011) can be used, whereas high-temporal-resolution (<2 days) and coarse-spatial-resolution data have been found suitable for regional and global-level inventories (Kasischke *et al.* 1993; Martín and Chuvieco 1995). With the availability of *Terra* and *Aqua* MODIS data, efforts have been made to develop biophysical products, namely MCD45 (Roy *et al.* 2006) and MCD64 (Giglio *et al.* 2009), which are useful for forest ecological studies including detection of burned areas at the global level. Other global burned-area data sets were also developed, from SPOT Vegetation and the Along Track Scanning Radiometer 2 aboard Envisat (Grégoire *et al.* 2003; Tansey *et al.* 2004).

For detecting burned areas at the local level, medium-resolution satellite data such as Landsat-MSS and Thematic Mapper have been increasingly used (Quintano *et al.* 2018; Teodoro and Amaral 2019). Using medium-resolution multispectral data, a variety of methods have been developed for detecting burned areas, including spectral indices (Tucker 1979), surface temperature inversion (Mukherjee *et al.* 2018), principal component analysis (Richards 1984), image classification (Mitri and Gitas 2004), neural networks (Gómez and Martín 2011), and spectral mixture analysis (Smith *et al.* 2007).

Several studies have been carried out to assess burned areas using remote sensing techniques (Meng *et al.* 2017; Chuvieco *et al.* 2019). For regional-level studies, NASA's MCD64A1 and MCD45A1 burned-areas products have been operationally used. However, because of their coarser spatial resolutions, these products are not able to capture small fires (<50 ha), whose impact on terrestrial environments is empirically known but poorly quantified and is often excluded from global earth system models. Some efforts have been made to address this issue. Boschetti *et al.* (2015) developed a methodology for fusing multitemporal Landsat Enhanced Thematic Mapper Plus data and a MODIS active fire product for mapping burned areas at 30-m resolution, which was in good agreement with ground data. In yet another development, Long *et al.* (2019) proposed an automated method of generating 30-m-resolution global-scale annual burned-area maps from time series of Landsat images. In order to capture fire events of smaller dimensions

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Modelling, Representation, and Visualization of the Remote Sensing Data for Forestry Management

Remote sensing data includes aerial photography, videography data, multispectral scanner (MSS), Radar, and laser to map and understand various forest cover types and features. An accurate digital model of a selected forest type is developed using forest inventory data in educational and experimental forestry and extensive databases. It includes the formalization and compilation of methods for integrating forest inventory databases and remote sensing data with three-dimensional models for a dynamic display of forest changes.

Big data technology employs vast amounts of forestry data for forestry applications that require real-time inquiry and calculation. The techniques and strategies of forestry data analysis are integrated into the big data forestry framework, enabling interfaces that other Programmes may call. Virtual Reality addresses constraints in forest management such as temporal dependence, irreversibility of decisions, spatial-quantitative change of characteristics, and numerous objectives. Virtual representations integrate various computer graphics systems with display and interface devices to create a spatial presence in an interactive 3 D environment. Visualization of plant species' growth patterns, changes in species and their composition, and other morphological properties of forests are enhanced using machine learning and regression analysis methods as part of a digital model. In modelling, deep learning (DL) replicates expert observations on hundreds or thousands of hectares of trees.

Remote sensing is being used to map the distribution of forest resources, global changes in flora with the seasonal variations, and the 3D structure of forests. Graphic Information System (GIS) based visualizations depict dynamics through animations and 3D geo model visualizations and allow advanced spatial analytics and modelling in geographical phenomena for forest management. Digital forest modelling includes integrating forest inventory data, forest inventory database formation, graphics objects of forest inventory allocations with a digital forest model, and technology for visualizing forest inventory data. It helps forecast changes and visualizes situational phenomena occurring in forests using data and models involving spatial-temporal linkages.

Standard aerial shots capture images that view unseen components to the naked eye, such as the Earth's surface's physical structure and chemical composition. The challenges in remote sensing models include insufficient Remote Sensing (RS), spatial, spectral, and temporal resolution to detect degradation accurately. High costs of RS, the gap between operational and scientific uses, and lack of information sharing are some of the challenges of RS for forest management. The list of topics of interest include but are not limited to the following:

- Advancement of forest surveillance through Geographical Information Systems
- State of the art and perspectives of modelling and visualization framework for Forest type mapping and assessment of distribution
- Futuristic Satellite data analysis for stock maps and forest inventory analysis
- Big data-enabled GIS framework for forest management information
- AI-based Space Remote Sensing For Forest Ecosystem Assessment
- Enhanced visualization through deep learning for forest management solutions
- Novel approaches of multi-temporal satellite data using digital image analysis for forest management
- Advance representation of discrete objects and continuous fields in virtual environments through VR framework
- Database framework for regional and plot-based forest allotment data for model representation and visualization
- Development of scalable models for area-based metrics from Light Detection and Ranging (lidar) devices and photographic structure-for-motion (SFM)

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Digital Elevation Model Technologies and Applications
The DEM Users Manual, 3rd Edition

Edited by David F. Maune, PhD, CP and Amar Nayegandhi, CP, CMS

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14. DEM User Requirements & Benefits
    David F. Maune
15. Quality Assessment of Elevation Data
    Jennifer Novac

Appendix A. Acronyms

Appendix B. Definitions

Appendix C. Sample Datasets

This book is your guide to 3D elevation technologies, products and applications. It will guide you through the inception and implementation of the U.S. Geological Survey's (USGS) 3D Elevation Program (3DEP) to provide not just bare earth DEMs, but a full suite of 3D elevation products using Quality Levels (QLs) that are standardized and consistent across the U.S. and territories. The 3DEP is based on the National Enhanced Elevation Assessment (NEEA) which evaluated 602 different mission-critical requirements for and benefits from enhanced elevation data of various QLs for 34 Federal agencies, all 50 states (with local and Tribal input), and 13 non-governmental organizations.

The NEEA documented the highest Return on Investment from QL2 lidar for the conterminous states, Hawaii and U.S. territories, and QL5 IfSAR for Alaska.

Chapters 3, 5, 8, 9, 13, 14, and 15 are "must-read" chapters for users and providers of topographic lidar data. Chapter 8 addresses linear mode, single photon and Geiger mode lidar technologies, and Chapter 10 addresses the latest in topo-bathymetric lidar. The remaining chapters are either relevant to all DEM technologies or address alternative technologies including photogrammetry, IfSAR, and sonar.

As demonstrated by the figures selected for the front cover of this manual, readers will recognize the editors' vision for the future – a 3D Nation that seamlessly merges topographic and bathymetric data from the tops of the mountains, beneath rivers and lakes, to the depths of the sea.

Co-Editors

David F. Maune, PhD, CP and
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